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Institutional Opening-Up, Enterprise Digital Transformation and High-Quality Development: Evidence from China's Cross-Border E-commerce Comprehensive Pilot Zones

Xinqi Zhang

College of International Education, Xinjiang Agricultural University, Urumqi, China
1840929166@qq.com

Abstract. China pushes institutional opening-up and digital economic development at the same time. Under this background, Cross-Border E-Commerce Comprehensive Pilot Zones (CBEC Pilot Zones) become an important test platform for foreign trade system innovation. Current micro-level research still leaves room for further exploration. Few studies talk about how this policy affects firms' digital development decisions and what economic results the policy brings later. This paper treats the gradual expansion of pilot cities as a natural experiment. It uses panel data of A-share listed companies to build a multi-period difference-in-differences model. The paper carries out baseline estimation, reliability tests, group difference analysis, mechanism identification and economic result tests step by step. The study finds that CBEC Pilot Zones greatly lift the digital transformation level of firms in pilot cities. This main result stays true after many reliability checks. The mechanism tests show three main ways for the policy to work. First, the policy helps firms enter more overseas markets. Second, it lets firms feel less worry about unstable outside business environment. Third, it pushes companies to spend more money on research and development. Non-state-owned firms and manufacturing firms gain more benefits from this policy. Further tests on economic results tell us digital transformation raises firms' total factor productivity and strengthens supply chain stability. In this way, benefits from institutional opening-up turn into better production efficiency and stronger ability to fight business risks. This paper proves the positive effects of cross-border e-commerce pilot zones on firms from micro evidence. It adds three logic paths through market expansion, risk expectation and innovation investment to explain how institutional opening-up changes digital development. It also provides real data to help governments better arrange pilot zones, support high-quality foreign trade growth and keep industrial chain safe with digital tools.

Keywords: institutional opening-up, Cross-Border E-Commerce Comprehensive Pilot Zones, enterprise digital transformation, difference-in-differences, supply chain resilience

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1. Introduction

Cross-Border E-Commerce Comprehensive Pilot Zones act as a typical policy tool for institutional opening-up in foreign trade. These zones do not only offer short-term incentives like traditional export tax rebates or financial subsidies. Instead, they rebuild the whole system around cross-border trade rules, supervision processes and digital service systems. The "six systems and two platforms" framework brings customs clearance, tax collection, payment, logistics, finance and information services into one unified management system. It rebuilds work processes and adds digital tools to cut institutional costs for firms running cross-border businesses [1]. Hangzhou became the first pilot city in March 2015. After that, the central government expanded the pilot scope in several rounds. Up to now, 178 cities have joined the pilot list. The pilot network covers eastern, central and western areas, linking inland regions with overseas markets. According to *China E-Commerce Development Report (2024)* released by the Ministry of Commerce, China's cross-border e-commerce import and export volume hit more than 2.63 trillion yuan in 2024. Trade volume from pilot zones takes up over 95% of the national total. At the same time, digital transformation becomes a key way for firms to raise organization efficiency, respond faster to market changes and cooperate better with supply chain partners. However, existing studies lack direct micro evidence to explain how opening-up policies targeting rule connection and system coordination change firms' digital investment and internal organization adjustments.

To solve this question, this paper picks Shanghai and Shenzhen A-share listed firms from 2010 to 2023 as research samples. It takes the gradual launch of CBEC Pilot Zones as a natural experiment. The multi-period difference-in-differences method is used to judge how institutional opening-up affects enterprise digital transformation. The paper also analyzes the working channels and final economic results of the policy. This study may make three new contributions to existing research. First, it adds firms' sense of uncertainty into the analysis framework to explain the working mechanism. Most former studies focus on easing financing limits, enlarging market space or gathering talents. This paper talks about how pilot zones reduce firms' worry over unstable outside institutional environment. Such changes make firms have better judgment on future profits from digital investment. Second, the research puts "institutional opening-up – digital transformation – high-quality development" into one complete analysis frame. It checks total factor productivity and supply chain resilience together. The paper evaluates micro economic value of pilot zone policies from two sides: efficiency improvement and risk resistance. Third, it divides samples by ownership type and industry type to carry out group difference analysis. The results show different policy gains among different firm groups. These real data can help governments carry out pilot zone construction in a more targeted way later.

2. Institutional background and research hypotheses

2.1. Institutional background

CBEC Pilot Zones serve as a key practice carrier for China to push institutional opening-up. In March 2015, Hangzhou became the first pilot city. In January 2016, the State Council approved the second batch of pilots, including 12 cities: Tianjin, Shanghai, Chongqing, Hefei, Zhengzhou, Guangzhou, Chengdu, Dalian, Qingdao, Shenzhen, Suzhou and Ningbo. The total number of pilot cities reached 13. Later, several rounds of expansion made the pilot policy cover cities across the whole country in layers. Unlike traditional foreign trade support policies that mainly give subsidies or rewards, pilot zones focus on system tests to solve real problems in cross-border trade. Policy

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contents cover easier customs clearance, tax management, cross-border payment, logistics cooperation and financial services. These rules lower the entry barrier for firms to start cross-border business. Small and medium-sized manufacturers can connect with international markets at much lower costs. Past studies prove that setting up pilot zones raises local cross-border e-commerce export volume. Such effects come from easier financing and lower trade costs [1]. Other evidence shows matching system reforms improve export performance of firms within pilot areas. The main working paths include lower tax burden and better financing environment [2].

2.2. Theoretical analysis and research hypotheses

2.2.1. Logic of institutional opening-up driving enterprise digital transformation

First, pilot zones change cross-border trade scenes and push firms to carry out digital transformation. Cross-border e-commerce moves inquiry, order placing, warehouse management, logistics, payment and after-sales services onto online platforms. If firms keep using old offline foreign trade processes, they can hardly meet market needs for fast order response and data cooperation. As cross-border business grows, firms need stronger ability to process data, draw customer portraits, manage stock and connect supply chains. Digital transformation is no longer just a tool to improve internal management. It becomes a basic ability to fit new trade modes. Research by Li Xiangqian and other scholars [3] on CBEC Pilot Zones points out institutional opening-up helps firms finish digital transformation, especially supporting the construction of digital infrastructure and the use of digital technology.

Second, institutional opening-up changes competition environment for firms. Pilot zones lower institutional barriers for firms to enter global markets. Meanwhile, firms face stricter rules from overseas clients on delivery speed and price transparency. To keep global competitiveness, companies need digital tools to improve production plans, quality control and market feedback speed. Related studies show institutional opening-up can raise innovation quality and production efficiency through better resource allocation and international knowledge learning [4, 5]. Following this logic, firms with more outside information and market resources have stronger motivation to add digital technology into production, management and sales links. Based on the above analysis, this paper puts forward the first hypothesis:

Hypothesis 1: Institutional opening-up represented by CBEC Pilot Zones will raise enterprises' digital transformation level.

2.2.2. Transmission paths and economic results of institutional opening-up

First, institutional opening-up can push digital transformation by lowering firms' sense of uncertainty. CBEC Pilot Zones offer clear institutional rules on trade operations, supervision processes and policy services. These rules reduce firms' fear of sudden changes in outside systems. As a result, companies are more willing to build digital systems and rebuild internal work processes. Existing studies prove policy uncertainty stops firms from making innovations and long-term investments. Tong Jiadong and Li Shengqi [6] find lower trade policy uncertainty helps import and export firms create new products. Fang Mingyue and other researchers [7] state digital upgrades can ease business risks caused by policy uncertainty. The reason is digital technology improves firms' ability to deal with information. We can draw a conclusion here: when pilot zones cut firms' sense of uncertainty over cross-border business environment, firms form stable expectations for transformation and increase digital investment.

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Hypothesis 2: CBEC Pilot Zones raise enterprises' digital transformation level by reducing firms' sense of uncertainty.

Second, institutional opening-up speeds up digital transformation by offering more overseas market chances. CBEC Pilot Zones cut institutional barriers for firms to reach foreign markets. Companies can contact overseas buyers, get international orders and expand sales channels more easily. Wider market coverage makes business far more complex. Firms need to deal with different local consumer preferences, delivery time limits, after-sale rules and compliance demands at the same time. To handle such complexity, companies must rely on digital systems to improve order processing, customer identification, stock arrangement and supply chain cooperation. Higher overseas income not only means larger sales scale, but also creates stronger real demand for digital transformation.

Related papers support this judgment. Yang Shenggang and other scholars [8] find cross-border e-commerce raises firms' international operation level. Supply chain optimization, easier financing and digital transformation play key roles in this process. Xue Anwei and other researchers [9] explain from another angle: digital transformation helps firms expand overseas markets through cost control, innovation and supply chain effects. We can see overseas market expansion and digital transformation promote each other. After pilot zone policies open up cross-border business scenes, firms take active digital upgrades to fit global competition. Based on this, the paper puts forward the third hypothesis:

Hypothesis 3: CBEC Pilot Zones raise enterprises' digital transformation level by expanding overseas market chances.

Third, institutional opening-up pushes digital transformation by increasing research and development investment. Digital transformation is not just buying software or joining online platforms. It involves data management, technology learning and full reconstruction of internal organization processes. CBEC Pilot Zones cut trade costs, improve financing conditions and expand market demand. These changes free more resources for firms. At the same time, competition from global markets pushes companies to upgrade their technology. Better resource conditions and higher competition pressure together drive firms to spend more on research and development. Dong Wenting and other scholars [10] find a positive cycle between research investment and innovation ability: more research money improves innovation ability, and stronger innovation ability encourages more investment in research. Song Xianzhong and Han Yongfei [11] also discover digital upgrades and research innovation can support each other. So pilot zone policies may drive enterprise digital transformation by stimulating research spending. Based on the above logic, this paper sets the fourth research hypothesis:

Hypothesis 4: CBEC Pilot Zones raise enterprises' digital transformation level by increasing firms' research and development investment.

Furthermore, enterprise digital transformation acts as a key link to turn institutional opening-up into high-quality development results. Institutional opening-up can widen overseas business space for market players and offer stable institutional expectations. But policy benefits can only turn into better development quality if firms own matching organization and technology abilities. Digital transformation raises information processing efficiency, cuts internal cooperation costs, strengthens supply chain coordination and improves firms' ability to deal with outside shocks. Existing empirical studies prove digital transformation lifts total factor productivity, innovation performance and long-term business results [12, 13]. Under the background of CBEC Pilot Zones, digital transformation helps firms turn market chances brought by institutional opening-up into efficiency improvements and ability accumulation, so as to push high-quality development of enterprises.

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Hypothesis 5: CBEC Pilot Zones push enterprises to carry out digital transformation, and further drive high-quality development of enterprises.

3. Research design

3.1. Data sources

This paper selects Shanghai and Shenzhen A-share listed firms from 2010 to 2023 as research samples. Basic firm information and financial data come from CSMAR Database. The list of CBEC Pilot Zones is sorted out manually according to all official approval documents from the State Council, and matched with the registered city of each listed company. City-level data are taken from *China City Statistical Yearbook*. Considering policy background and data availability, the paper follows these rules to screen samples: First, remove samples from financial industries. Second, exclude ST and *ST firms with abnormal operation status. Third, drop firms whose registered cities change and switch their policy treatment status. Fourth, delete observations with serious missing key variable values. Fifth, shrink continuous variables at the 1% and 99% levels each year to reduce the influence of extreme values. Finally, the paper gets 23,357 firm-year observation records.

3.2. Model setting

This paper uses a multi-period difference-in-differences model to estimate how pilot zone policies affect enterprise digital transformation. The specific model setting is shown below:

$$\mathrm{lnDigTrans}_{i,t}=\alpha_0+\beta_1\mathrm{Treat\_Post}_{j,t}+\sum\gamma_k\mathrm{Controls}_{k,i,t}+\mu_i+\nu_t+\varepsilon_{i,t} \tag{1}$$

In the formula, i stands for the firm, j stands for the city where the firm registers, and t stands for the year. $lnDigTrans_{i,t}$ is the explained variable, which measures the digital transformation level of firm i in year t. $Treat_Post_{j,t}$ is the core explanatory variable. If city j where the firm registers becomes a CBEC Pilot Zone in year t, this value equals 1; otherwise it equals 0. $Controls_{k,i,t}$ stands for control variables including firm financial performance and corporate governance factors. μ_i controls fixed individual differences of each firm that do not change over time. ν_t controls macro yearly shocks. Firms in the same city may face shared unobserved local factors, so standard errors are clustered at the city level. $\varepsilon_{i,t}$ means random disturbance term.

3.3. Variable description

3.3.1. Explained variable: enterprise digital transformation

This paper builds a keyword database for digital transformation based on annual report texts of listed companies. It counts the frequency of keywords in multiple categories: artificial intelligence technology, blockchain technology, cloud computing technology, big data technology, digital technology application, intelligent manufacturing, modern information system and organization empowerment. After adding 1 to the total count, the paper takes natural logarithm to get the enterprise digital transformation level index ($lnDigTrans$).

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3.3.2. Core explanatory variable: cross-border e-commerce comprehensive pilot zone policy

This paper identifies the policy status of each firm's registered city based on seven batches of official CBEC Pilot Zone city lists published by the State Council, and sets the treatment group dummy variable Treat. The year when a city is approved as a CBEC Pilot Zone acts as the policy cut-off point to build the post-policy dummy variable Post: the value equals 1 in the policy launch year and all later years, and equals 0 before the policy comes out. Considering possible time lag in policy implementation, if the official list is released in the first half of a year, the policy is counted as taking effect in that year. If the list comes out in the second half of a year, the policy is counted as taking effect in the next year. On this basis, the interaction term $Treat_{Post_{j,t}}$ is generated. The value equals 1 when city j is within the CBEC Pilot Zone range in year t, and equals 0 in other cases.

3.3.3. Control variables

To control firm-level factors that may influence digital transformation, this paper includes two types of control variables. The first type covers financial and operation features: firm size (Size), asset-liability ratio (Lev), total asset return rate (Roa), operating cash flow (Cfo) and operating income growth rate (Growth). The second type includes governance structure features: board size (Board), institutional investor shareholding ratio (Institution), shareholding ratio of the largest shareholder (Top1) and independent director proportion (Indboard). Table 1 shows the mean value, standard deviation and value range of each main variable. All data stay within reasonable intervals without obvious abnormal values.

Table 1. Descriptive statistics of main variables

Variable	N	Mean	SD	Min	Max
lnDigTrans	29931	1.3319	1.3298	0.0000	6.2672
Treat_Post	29931	0.4287	0.4949	0.0000	1.0000
Size	29931	22.4609	1.3185	19.3678	26.7616
Lev	29931	0.4541	0.2006	0.0424	0.9161
Roa	29931	0.0338	0.0618	-0.4582	0.2357
Cfo	29931	0.0483	0.0697	-0.2262	0.2735
Growth	29931	0.1543	0.4586	-0.6823	6.4437
Board	29931	2.1358	0.1985	1.6094	2.7081
Institution	29931	46.9282	23.7552	0.1119	93.0852
Indboard	29931	0.3755	0.0544	0.2857	0.6000
Top1	29931	34.9332	15.1858	8.0700	78.0200

4. Empirical analysis

4.1. Baseline regression

Table 2 shows baseline estimation results of how pilot zone policies affect enterprise digital transformation. Column (1) only adds firm fixed effects and year fixed effects. The coefficient of Treat_Post is positive and passes the significance test at the 1% level. This result tells us firms in pilot cities clearly lift their digital transformation level after the policy launch. Column (2) further

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adds financial control variables including firm size, asset-liability ratio and total asset return rate. The core coefficient still keeps a significantly positive value. Column (3) brings in governance variables such as board size and institutional shareholding ratio. The coefficient of Treat_Post remains significant at the 1% level. The above results prove that after controlling fixed firm differences, yearly macro shocks and main firm-level factors, CBEC Pilot Zones still create a stable positive effect on enterprise digital upgrades. Hypothesis 1 gets full support.

Table 2. Baseline regression

Variable	(1)	(2)	(3)
	lnDigTrans	*lnDigTrans*	*lnDigTrans*
Treat_Post	0.0855^{***}	0.0733^{***}	0.0723^{***}
	(0.0154)	(0.0157)	(0.0156)
Control Variables	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Observation	29931	29931	29931
R^2_adjusted	0.7260	0.7370	0.7378

Note: *, ** and *** mean significant at the 10%, 5% and 1% levels respectively. Numbers inside brackets stand for robust standard errors. All tables below follow this rule.

4.2. Parallel trend test

The parallel trend assumption acts as a key precondition to identify causal effects with difference-in-differences models. Before policy implementation, firms in treatment groups and control groups should show similar change trends of digital transformation. If the two groups already have systematic differences before the policy comes out, baseline regression results may reflect original gaps instead of real policy impacts. This paper uses the event study method to test parallel trends. It takes the year right before policy launch as the benchmark group and observes dynamic effects in years before and after the policy.

$$\mathrm{lnDigTrans}_{i,t}=\alpha_0+\sum_{k=-6,k\neq-1}^{6}\beta_k D_{j,t}^{k}+\sum_k \gamma_k \mathrm{Controls}_{k,i,t}+\mu_i+v_t+\varepsilon_{i,t} \tag{2}$$

In the formula, $D_{j,t}^{k}$ is a dummy variable of relative policy time. k means the relative year when city j becomes a CBEC Pilot Zone. This paper combines all years six years or earlier before the policy into the "-6" group, and all years six years or later after the policy into the "6" group. $D_{j,t}^{0}$ stands for the exact policy launch year, and the year before launch serves as the benchmark group. If coefficients of all pre-policy years are not significant, we can accept the parallel trend assumption. Figure 1 shows estimation results under the 95% confidence interval.

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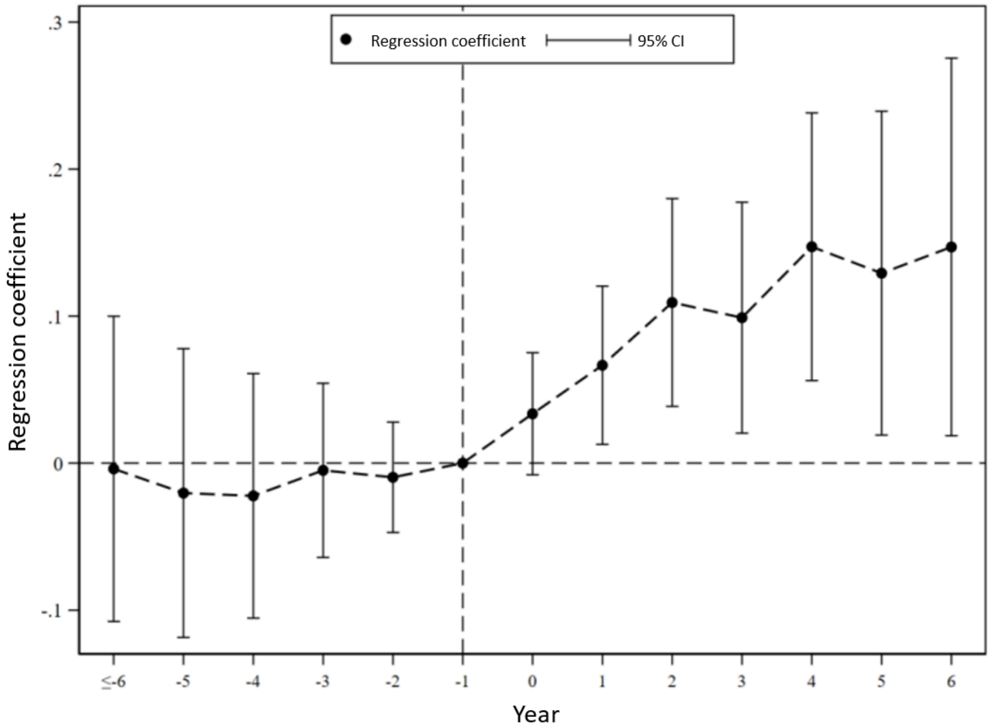

Figure 1. Parallel trend test

From Figure 1, estimation coefficients of periods -6 to -2 before the policy move around zero. All confidence intervals cover zero without continuous rising or falling trends in advance. This means before pilot zone policies launch, firms in pilot cities and non-pilot cities do not have obvious systematic gaps in digital transformation changes. The parallel trend assumption holds true. After the policy takes effect, estimation coefficients turn positive and rise in general. It shows policy effects carry cumulative dynamic features: pilot zones bring positive influences starting from the launch year. The promoting effect becomes stronger as system rules gradually land and firms get more familiar with new policies.

4.3. Reliability tests

4.3.1. Placebo test

To check whether baseline results are affected by unobserved random city-level shocks, this paper carries out a placebo test to improve reliability of causal identification.

The specific method builds counter-factual policy shocks at the city level. First, the paper randomly picks the same number of "fake pilot cities" as real CBEC Pilot Zones from all sample cities, and generates the fake policy variable $Treatpost_{fake}$. Second, it replaces the real policy variable with this fake variable and runs regression under the same control variable and fixed effect settings as the baseline model. Third, repeat the random sampling and estimation process 1,000 times, and record the estimated coefficient of $Treatpost_{fake}$ each time to form an empirical distribution of fake policy effects. The results are shown in Figure 2.

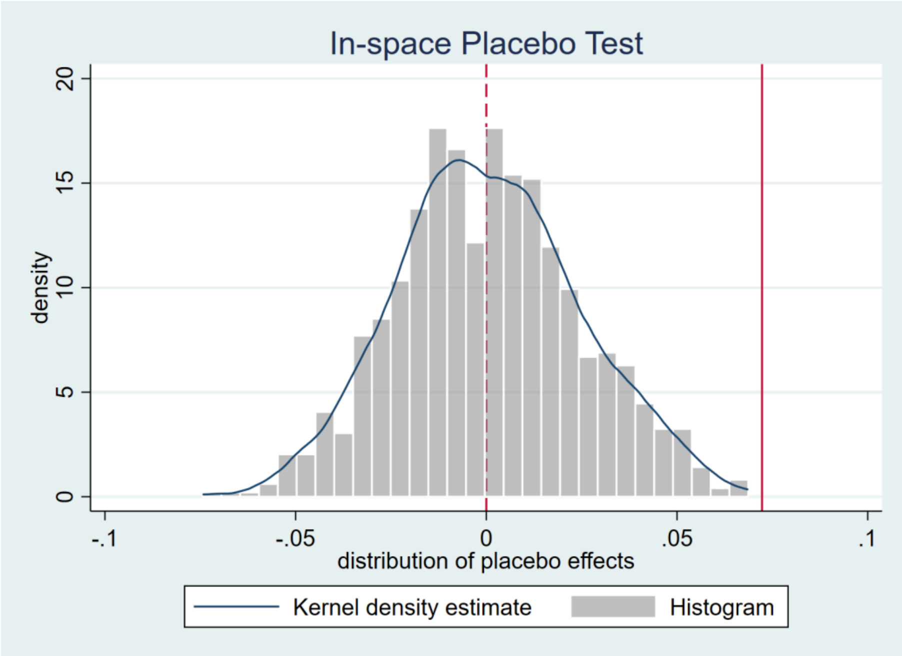

Figure 2. In-space placebo test

Figure 2 displays the distribution of estimated coefficients from fake treatment groups. Coefficients from 1,000 random simulations mostly gather around zero and form an approximate normal distribution. By contrast, the baseline estimated coefficient of real pilot zone policies clearly sits at the right tail of this distribution, with obvious gaps between real and fake coefficients. This result proves the policy effect found in this paper does not come from random city-level shocks or missing variables. It is far more likely produced by CBEC Pilot Zone policies themselves, so the baseline conclusion has stronger causal explanatory power.

4.3.2. Replace core explained variable

To test whether conclusions rely on single variable measurement, this paper replaces the enterprise digital transformation index with two new proxy variables. Table 3 shows related results. Column (1) uses investment in digital intangible assets of firms as the proxy variable. The coefficient of pilot zone policy stays positive and significant at the 1% level. Column (2) switches to the CSMAR digital transformation index as the explained variable. The policy effect also passes the 1% significance test. We can see no matter we use text keyword indexes, digital intangible asset investment or third-party digital indexes, CBEC Pilot Zones keep a stable positive promoting effect on enterprise digital transformation. The baseline conclusion does not depend on one single measurement method.

Table 3. Replace core explained variable

Variable	(1)	(2)
	DigIntangible	*DigIndex*
Treat_Post	0.0072***	0.6088***
	(0.0025)	(0.0889)
Control Variables	Yes	Yes

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Table 3. (continued)

Firm Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes
Observation	29222	28561
R^2_adjusted	0.6259	0.8500

4.4. Heterogeneity analysis

4.4.1. Ownership heterogeneity

State-owned firms and non-state-owned firms differ in resource access, operation flexibility and policy response speed. Digital effects of pilot zone policies may change with ownership types. This paper divides samples into state-owned firms and non-state-owned firms based on actual controller nature, and runs separate estimations. Column (1) and Column (2) in Table 4 show coefficients of Treat_Post are positive and significant for both groups. It means the policy brings promoting effects to all firms regardless of ownership. However, the coefficient value of non-state-owned firms is larger. Non-state-owned firms respond more actively to market chances and institutional convenience brought by pilot zones, so their digital transformation levels rise more greatly.

4.4.2. Manufacturing industry heterogeneity

Manufacturing firms differ from non-manufacturing firms in digital production processes, technology absorption and cross-border supply chain participation. Policy effects also show industry heterogeneity. The paper divides samples into manufacturing and non-manufacturing groups following national industrial classification standards. Column (3) and Column (4) in Table 4 tell us the Treat_Post coefficient of manufacturing samples is positive and significant at the 1% level, while the coefficient of non-manufacturing samples fails the significance test. This result shows pilot zone policies mainly release digital promoting effects through manufacturing firms. The reason may be manufacturing cross-border orders, production coordination and supply chain management scenes depend more heavily on digital technology.

Table 4. Heterogeneity analysis

Variable	(1) State-owned Firms	(2) Non-state-owned Firms	(3) Manufacturing	(4) Non-manufacturing
	lnDigTrans	*lnDigTrans*	*lnDigTrans*	*lnDigTrans*
Treat_Post	0.0436*	0.1039***	0.1509***	0.0240
	(0.0233)	(0.0214)	(0.0254)	(0.0199)
Control Variables	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Observation	12519	17358	11060	18839
R^2_adjusted	0.7275	0.7497	0.7439	0.7466

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5. Mechanism test

This paper identifies three working paths: market expansion, risk reduction and innovation stimulation. It sets the following mechanism test model. $Mechanism_{i,t}$ stands for corresponding mechanism variables.

$$\mathrm{Mechanism}_{i,t}=\alpha_0+\alpha_1\mathrm{Treat\_Post}_{j,t}+\sum\alpha_k\mathrm{Controls}_{k,i,t}+\mu_i+\lambda_t+\varepsilon_{i,t} \tag{3}$$

5.1. Growth of overseas income

Pilot zones cut costs for firms to run overseas businesses through easier customs clearance, tax rules, logistics support and cross-border service platforms. Firms can more easily enter global markets and raise overseas income. Larger overseas market scale makes firms face stricter demands on customer response, quality control and supply chain cooperation. Companies then need digital tools to optimize production flows, order management and customer services. This forms a transmission chain from market expansion to digital transformation.

Table 5 shows related test results. Column (1) takes overseas income of firms as the explained variable. The coefficient of Treat_Post is positive and significant at the 1% level. It proves pilot zone policies indeed expand firms' overseas income scale. Column (2) further shows the coefficient of ForeignIncome is positive and significant at the 1% level. Higher overseas income comes together with higher digital transformation levels. Results from two steps support the channel judgment: policies push overseas business expansion, and overseas business expansion further speeds up digital transformation.

Table 5. Growth of overseas income

Variable	(1)	(2)
	ForeignIncome	*lnDigTrans*
Treat_Post	3.0394***	
	(0.8896)	
ForeignIncome		0.0006***
		(0.0001)
Control Variables	Yes	Yes
Firm Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes
Observation	29586	29586
R^2*_adjusted*	0.5702	0.7390

5.2. Reduction of uncertainty perception

Frequent changes in macroeconomic policies make firms harder to judge future business environments. Firms tend to delay or cut long-term investment like digital transformation. As a relatively stable trade institutional arrangement, CBEC Pilot Zones stabilize firms' expectations through clear rules, optimized services and lower cross-border trade frictions. Firms feel less uncertainty about economic policies, so they become more willing to carry out long-term digital construction.

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Table 6. Reduction of uncertainty perception

Variable	(1)	(2)
	EPU	*lnDigTrans*
Treat_Post	-0.0047**	
	(0.0023)	
EPU		-0.1810***
		(0.0419)
Control Variables	Yes	Yes
Firm Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes
Observation	29383	29383
R^2_adjusted	0.3106	0.7402

Table 6 shows test results of the uncertainty perception channel. Column (1) takes firms' economic policy uncertainty perception (EPU) as the explained variable. The coefficient of Treat_Post equals -0.0047 and passes the 5% significance test. It means pilot zone policies lower the uncertainty feeling of firms. Column (2) adds EPU into the digital transformation model. Its coefficient is -0.1810 and significant at the 1% level. Lower uncertainty perception leads to higher digital transformation levels of firms. The above results prove improved risk expectation acts as an important intermediate channel for pilot zone policies to influence enterprise digital transformation.

5.3. Rise in research and development investment

Pilot zone policies also work through the research and development investment channel. Wider overseas markets raise global standards for product quality, response speed and technical content. Firms have to invest more in research to build technical abilities and form competitive advantages different from other players. Table 7 shows related results. Column (1) takes research and development intensity (RD) as the explained variable. The coefficient of Treat_Post is 0.0004 and significant at the 10% level. It proves the policy encourages firms to increase research spending. Column (2) puts RD into the digital transformation model. Its coefficient is 2.4868 and significant at the 1% level. More research investment greatly lifts enterprise digital transformation levels. We can see innovation resource investment forms an important transmission link for policy effects.

Table 7. Rise in research and development investment

Variable	(1)	(2)
	RD	*lnDigTrans*
Treat_Post	0.0004*	
	(0.0002)	
RD		2.4868***
		(0.7999)
Control Variables	Yes	Yes
Firm Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes

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Table 7. (continued)

Observation	29931	29931
R^2*_adjusted*	0.7552	0.7380

6. Test on economic results: high-quality development and high-level safety

We need to further explain how enterprise digital transformation extends policy effects from institutional opening-up to production efficiency and supply chain safety. Digital transformation is not only a simple upgrade of management tools. It restructures internal resource allocation, improves information exchange between upstream and downstream partners and strengthens firms' ability to fight outside shocks. The process influences long-term business performance and risk resistance at the same time.

Based on this, this paper tests economic results from two dimensions: high-quality development (total factor productivity) and high-level safety (supply chain resilience). It builds the following model. $Consequence_{i,t}$ stands for economic result variables.

$$\mathrm{Consequence}_{i,t}=\beta_0+\beta_1\mathrm{lnDigTrans}_{i,t}+\sum_k \beta_k \mathrm{Controls}_{k,i,t}+\mu_i+\lambda_t+\varepsilon_{i,t} \quad (4)$$

6.1. Total factor productivity

Total factor productivity acts as a key index to judge enterprise high-quality development. Digital transformation optimizes production processes, improves matching of production factors and cuts internal transaction costs to release efficiency potential. Column (1) of Table 8 takes total factor productivity (TFP_LP) as the explained variable. The coefficient of enterprise digital transformation index ($lnDigTrans$) is 0.0308 and significant at the 1% level. Digital transformation greatly raises firms' production efficiency. For firms in pilot zones, digital tools connect purchasing, production and sales links. These tools reduce wrong resource allocation and improve cooperation efficiency. Firms turn market chances brought by opening-up policies into higher productivity.

Results in Table 8 as a whole show digital transformation improves efficiency and strengthens supply chain stability at the same time. Column (2) takes supply chain resilience (supply_chain_resilience) as the explained variable. The coefficient of $lnDigTrans$ is 0.0281, also significant at the 1% level. Two results together tell us pilot zone policies push enterprise digital transformation, and finally bring both higher production efficiency and stronger supply chain stability. This reflects positive micro economic results of institutional opening-up.

6.2. Supply chain resilience

Supply chain resilience measures firms' ability to resist outside trade shocks and keep stable industrial chain operation. It forms important support for safe business operation under open environments. Results of Column (2) in Table 8 prove digital transformation clearly improves firms' ability to resist supply chain risks. The reason is digital platforms break information barriers between upstream and downstream partners. Firms can track real-time overseas supply and demand changes and find alternative suppliers. This lowers the risk of broken industrial chains caused by single markets or single partners, and weakens shocks from changes in international trade environments on business operation.

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Table 8. Test on economic results

Variable	(1) Total Factor Productivity	(2) Supply Chain Resilience
	TFP_LP	*supply_chain_resilience*
lnDigTrans	0.0308^{***}	0.0281^{***}
	(0.0036)	(0.0041)
Control Variables	Yes	Yes
Firm Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes
Observation	29931	29931
R^2_adjusted	0.8993	0.7077

7. Research conclusions and policy suggestions

This paper takes Shanghai and Shenzhen A-share listed firms from 2010 to 2023 as samples. It treats the gradual launch of CBEC Pilot Zones as a natural experiment and uses the multi-period difference-in-differences model to study how institutional opening-up affects enterprise digital transformation. The study draws four main conclusions. First, pilot zone policies greatly lift enterprise digital transformation levels, and this result stays true after multiple reliability tests. Second, mechanism tests show three working channels of the policy: market expansion, risk reduction and innovation stimulation. Larger overseas income creates stronger digital needs for firms to fit global markets. Lower uncertainty perception stabilizes long-term transformation expectations of companies. Higher research investment offers technical and resource support for digital upgrades. Third, heterogeneity results show non-state-owned firms and manufacturing firms respond more strongly to the policy. Fourth, tests on economic results find digital transformation further raises total factor productivity and strengthens supply chain resilience. Firms gain both better production efficiency and stronger risk resistance at the same time.

Conclusions of this paper offer useful suggestions to improve CBEC Pilot Zone construction and push enterprise digital transformation. First, governments should build long-term stable operation rules for pilot zones. They need to optimize pilot layout according to local foreign trade foundation and industrial structure. For areas with weak foreign trade bases, authorities should build better cross-border infrastructure and public service support. For areas with mature trade conditions, governments can test higher-level supervision cooperation and service innovation. Second, guide firms to take active digital layout instead of only adapting to policy requirements passively. Governments can offer digital transformation subsidies, tax cuts and one-stop digital service platforms to lower digital operation barriers for small and medium-sized firms. Third, strengthen support and supervision from capital markets. Improve digital finance and technology finance services to guide long-term capital to focus on real digital investment and performance improvements of firms. Fourth, push coordinated development of opening-up policies and digital policies. Rely on industrial internet, big data and intelligent logistics tools to empower all links of cross-border trade. Form a positive cycle where opening-up speeds up digital transformation, and digital transformation supports higher-level opening-up.

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