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Research article

Cross border e-commerce development and enterprise digital technology innovation—empirical evidence from listed companies in China

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ABSTRACT

As the main form of digital trade, cross-border e-commerce plays an important role, allowing China to expand its opening-up and promote the optimal foreign trade structure. It also provides opportunities for Chinese enterprises to develop digital technology. From the perspective of the establishment of China's cross-border e-commerce comprehensive pilot zone (CBECPZ), this article uses the multi-period DID method to examine the effects of cross-border e-commerce on enterprise digital technology innovation based on listed companies in the Shanghai and Shenzhen stock markets from 2007 to 2020. The CBECPZ dramatically promotes enterprise digital technology innovation. The mechanism test shows that the CBECPZ promotes digital technology innovation by financing constraint alleviation, digital transformation, and producer service industry agglomeration. The heterogeneity test shows that the direct effect is more significant in the enterprises of large-scale, non-state-owned, with high ICT correlation and in areas with strong government resource allocation capabilities. The research findings have important reference value for how to utilize cross-border e-commerce to promote digital technology innovation, and they also provide directional references for other developing countries to develop cross-border e-commerce.

1. Introduction

With the rise of technological revolution, digital technology such as artificial intelligence, big data, blockchain, and cloud computing have been widely developed and applied. Unlike general technology, digital technology is the core driving force for the development of the digital economy, and also the technological foundation for achieving deep integration between the digital economy and the real economy [1], driving the transformation and upgrading of China's economic structure. Due to the characteristics of digital technology, it is crucial to achieve innovation in digital technology, especially in key core digital technologies. In relevant researches, digital technology innovation is considered to be able to promote enterprise digital transformation, production efficiency, and market profitability [2]; It can also improve the quality of management decision-making and asset operation efficiency (Huang et al., 2023). Enterprises are the key players in digital technology innovation [3], but due to the high threshold, high cost, and

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imitatability of digital technology innovation [4], many enterprises are “unwilling” and “afraid” to engage in digital technology innovation.Therefore, it is necessary to explore how to effectively stimulate the willingness of enterprises to innovate in digital technology and enhance their digital technology innovation capabilities.

As a in-depth application of digital technology empowering trade development, cross-border e-commerce has experienced rapid development in China. According to customs data, from 2012 to 2023, the scale of cross-border e-commerce in China increased from CNY 2.1 trillion to CNY 16.8 trillion, with an average annual growth rate of 25.9 %. To promote the reform and development of cross-border e-commerce, the Chinese government is accelerating the establishment of cross-border e-commerce comprehensive pilot zones (CBECPZs). Since the first establishment of CBECPZ of Hangzhou in March 2015, the State Council has replicated and promoted CBECPZs like that in Hangzhou in more cities. By the end of 2022, China had established a total of 165 CBECPZs, covering 31 provinces, autonomous regions and municipalities across the country. Seemingly, cross-border e-commerce is currently the new form of foreign trade with the fastest development speed, greatest potential and strongest driving force in China.

In the State Council’s approval for the establishment of CBECPZs, “leveraging the positive role of cross-border e-commerce in assisting traditional industry transformation and upgrading, promoting enterprise digital technology innovation, and promoting foreign trade optimization and upgrading” was mentioned. The key question is, can cross-border e-commerce promote enterprise digital technology innovation? What is its theoretical support? Can empirical evidence be obtained for verification? Existing literatures on cross-border e-commerce mainly focused on its trade promotion effects. For example, are scholars have found that cross-border e-commerce can promote regional economic growth [5] and import and export trade [6,7], reduce trade costs [8–11]. Some scholars have also pointed out that cross-border e-commerce can improve business performance [12], promote enterprise exports [13,14], and improve consumer welfare (Brynjolfsson et al., 2003; Duch Brown et al., 2014). In recent years, with the continuous reform of cross-border e-commerce, and the acceleration of the establishment of CBECPZs, some scholars have begun to use the DID method to study the effectiveness of cross-border e-commerce reform from the perspective of CPECPZ. At the macro level, the establishment of CPECPZs has been proven to promote economic growth, inbound tourism, trade upgrading and export growth, and internationalization of the manufacturing industry [15–18], can reduce supply chain risks [19]. At the meso level, the establishment of CPECPZs can promote urban entrepreneurial vitality, urban carbon emissions efficiency, and urban residents’ tourism consumption [20–22]. At the micro level, the establishment of CPECPZs can increase enterprise exports, risk bearing levels and employee salaries, improve environmental performance, etc. [23–25], as well as household consumption levels and welfare [25]. In terms of entreprise innovation, Ni et al. [26] found that cross-border e-commerce can promote entreprise innovation by alleviating financing constraints and intensifying market competition. Shi and Yu [27] found that the establishment of CPECPZs can promote entreprise technology innovation by increasing entreprise profit, enhancing technology spillover, and promoting the integration of manufacturing and service industries. But there is no literature specifically exploring the effect of cross-border e-commerce on enterprise digital technology innovation.

In view of this, this article attempts to explore the effect of cross-border e-commerce on enterprise digital technology innovation from the perspective of the establishment of CBECPZ, and reveals the underlying mechanism. Meanwhile, based on the data of A-share listed companies in Shanghai and Shenzhen from 2007 to 2020, a multi-period DID method is used for empirical testing.The possible contributions of this article are as follows: first, it is a valuable supplement to the relevant theoretical research related to cross-border e-commerce from the perspective of exploring the effect the establishment of CBECPZs on enterprise digital technology innovation; second, it explores the effects of CBECPZs on digital technology innovation from the dimensions of financial constraint alleviation, digital transformation, and agglomeration of the producer service industry; third, the multi-period DID and instrumental variables methods are used to avoid the estimation bias caused by endogeneity problems, such as measurement error and reverse causation, in previous studies, and the conclusions are more reliable.

2. Theoretical mechanisms and hypotheses

This article argues that CBECPZs can promote enterprise digital technology innovation through three pathways: financing constraint alleviation, digital transformation, and producer service industry agglomeration. The specific mechanism of action is as follows.

2.1. The effect of financing constraint alleviation

Enterprise digital technology innovation requires a large amount of R&D funds [28–30]. According to financing constraint theory, the funding sources of enterprises are mainly divided into internal financing and external financing. The establishment of CBECPZs can alleviate external financing constraints for enterprises in the following ways. First, financial institutions within CBECPZs can provide strong financial support policies for cross-border e-commerce enterprises, which can provide financial support for enterprise research and development, help enterprises share the risks of research and development failures, and provide guarantees for enterprise digital technology innovation. Moreover, based on the application of cross-border e-commerce big data features, financial institutions can more accurately understand the development prospects of enterprises, control overall credit risks, and develop more precise financial support policies [31,32]. Second, the government has provided a large amount of fiscal support and tax subsidies to cross-border e-commerce enterprises. For example, in terms of fiscal support, the Hangzhou CBECPZ encouraged the cultivation of cross-border e-commerce entities, providing no more than CNY one million of fiscal support annually to cross-border e-commerce platforms, no more than CNY 2 million annually to enterprises exporting through models such as 9610, 9710, and 9810, and no more than CNY 2 million to enterprises conducting cross-border e-commerce export business through independent websites. In terms of tax subsidies, the government has introduced a “no invoice tax exemption” policy, which allows e-commerce enterprises in CBECPZs to enjoy value-added tax exemption and consumption tax exemption policies for goods exported without obtaining valid purchase certificates when certain conditions are met. These preferential fiscal support and tax subsidy policies directly reduce the tax burden on enterprises, increase the internal working capital of enterprises [33], and greatly alleviate the financial constraints cross-border e-commerce enterprises face when attempting to engage in digital technology innovation.

Based on the above analysis, this article proposes Hypothesis 1: the establishment of CBECPZs can improve enterprise digital technology innovation by alleviating financing constraints for enterprises.

2.2. The effect of digital transformation

Cross-border e-commerce has gone through a period of germination and growth and is currently in a mature stage, accelerating towards global digital trade. Against the background of trade digitalization, digital technology is developing rapidly, and digital technologies such as big data, cloud computing, artificial intelligence, blockchain, and other digital technologies have comprehensively penetrated all aspects of the cross-border e-commerce industry and have become important driving forces for model innovation and efficiency transformation of the cross-border e-commerce industry, promoting the digital transformation of cross-border e-commerce enterprises. Digital transformation can greatly promote business process reengineering. According to the theory of process reengineering, digital transformation can promote digital innovation in enterprises in the following ways. First, digital transformation can help enterprises reach the end users of their products through digital technologies such as data mining, information collection, and feedback; accurately identifying consumer needs and preferences; conducting targeted innovation; and improving innovation investment efficiency [34–37]. Second, digital transformation can improve the efficiency of internal and external information exchange within enterprises, reducing information asymmetry issues, and digital technology can be used to monitor risks in research and development activities, improving the success rate of digital innovation projects and promoting digital innovation in enterprises [38].

In addition, as a highland for the development of cross-border e-commerce, the establishment of CBECPZs has led to the agglomeration of a large number of upstream and downstream digital industries. From the positive externalities of agglomeration, digital transformation is conducive to the formation of cross-coupling relationships between enterprises in the information network space, weakening the incompressibility of tacit knowledge and allowing the accumulation of data elements in the network to generate new knowledge that can be infinitely reused. Then, through data elements and the "knowledge spillover" effect of the internet, information is transmitted to cluster enterprises, thereby enhancing their digital technology innovation capabilities [3,39].

Based on the above analysis, this article proposes Hypothesis 2: the establishment of CBECPZs can improve enterprise digital technology innovation through digital transformation.

2.3. The agglomeration effect of the producer services industry

While promoting the development of cross-border e-commerce, the establishment of CBECPZs will also drive the agglomeration of producer service industries such as financial payments, information technology, technology services, warehousing, and logistics; optimize the division of labour in cross-border e-commerce industries; expand the coverage of the industrial chain; and accelerate the integration of upstream and downstream industries [18,40]. At the same time, with the support of a series of preferential policies from central and local governments, a "depression effect" easily forms in CBECPZs. According to the classic theory of industrial agglomeration, the agglomeration of producer service industries can generate externalities through labour reservoirs, intermediate input sharing, and knowledge spillovers. First, the specialized agglomeration of producer service industries can provide convenient conditions for enterprises to share knowledge, technology, and processes, assist enterprises in reducing R&D innovation and production operation costs, and provide greater economic space for digital technology research and innovation within of enterprises (Eswaran and Kotwal,2002; [41]). Second, the diversified agglomeration of producer service industries can promote the formation of linkages between different industries within the agglomeration area, thereby improving resource integration and utilization efficiency and generating economies of scale and knowledge spillovers. Knowledge spillover helps to promote the cross-border integration of knowledge and technology from different industries, promote collaborative innovation in industries, and thus improve the level and efficiency of enterprise digital technology innovation. In addition, the agglomeration of producer service industries can narrow the physical distance between enterprises and increase mutual learning and face-to-face communication, which will help knowledge dissemination and technology collaborative innovation between enterprises, maximize technology spillover effects [30,42], and promote enterprise digital technology innovation.

Based on the above analysis, this article proposes Hypothesis 3: the establishment of CBECPZs can improve enterprise digital technology innovation through the agglomeration of producer service industries.

3. Research design and data description

3.1. Modelling and variable measurement

Considering the endogeneity problem in previous studies, this study intends to use the difference-in-differences (DID) method to test the effect of CBECPZs on enterprise digital technology innovation. By the end of 2022, a cumulative total of 165 Chinese cities were approved to become CBECPZs in seven batches: the second batch of 12 cities was established in January 2016, the third batch of 22 cities in July 2018, the fourth batch of 24 cities in December 2019, the fifth batch of 46 cities in May 2020, the sixth batch of 27 cities in January 2022, and the seventh batch of 33 cities in November 2022. Due to the availability of data from listed companies, the time interval of the data used in this article is 2007–2020, and since the fifth batch of cities was established in May 2020, the implementation period is less than one year, and the policy effect has not yet been fully released. The establishment of the first four batches of CBECPZs is taken as the research object, and pilot cities after the fifth batch are taken as the control group. Considering that the CBECPZ in each city is established in multiple phases, this article adopts the multi-period DID method to conduct regression analysis, and the specific model is shown in Equation (1).

$$Dinnov_{it} = \alpha + \beta Policy_{it} + \gamma X_{it+} Year + Prov + Industry + \mu_{it} \tag{1}$$

where i represents the enterprises; t represents the year; $Dinnov_{it}$ is the dependent variable of this article, representing the level of digital technology innovation in enterprises; $Policy_{it}$ is the core explanatory variable of this article, represented by the interaction term between the policy dummy variable and the time dummy variable; X_{it} represents a set of control variables; *Year*, *Prov,* and *Industry* denote year, province, and industry fixed effects, respectively; and μ_{it} is a random disturbance term that obeys the assumption of being independent and identically distributed (iid).

(1) Explained variable (*Dinnov*): "digital technology innovation". According to the research methods of Chen et al. (2019) and Yang (2022), the number of patent applications related to digital technology is used to measure the level of enterprise digital technology innovation. Specifically, Python software was used to extract the keywords related to digital technology based on the "Statistical Classification of Digital Economy and Its Core Industries (2021)" of the China Statistics Bureau and the work reports of the Chinese government. Then, the keywords related to digital technology were matched with the information of China's patent texts to obtain the number of patent applications related to digital technology innovation by IPC number. After eliminating the abnormal data, the keywords were matched with the IPC classification number of invention patents and utility model patents of listed companies in the database of the China Research Data Service Platform. Finally, the number of digital technology patent applications was obtained, and the natural logarithm of the number of digital technology patents was taken after adding 1 to overcome the right-skewed distribution problem of patent data.

(2) Core explanatory variables (*Policy*). The core explanatory variable is the shock variable of the CBECPZ pilot policy ($Treat_i$ $*Post_t$). The policy dummy variable $Treat_i$ and the time dummy variable $Post_t$ are generated based on whether the sample city became a pilot city of the comprehensive pilot zone and when it was established, and the interaction term Policy is generated by assigning values to them.

(3) Control variables (*X*). With reference to the relevant literature, the following control variables are selected: the enterprise scale (size), measured by the natural logarithm of total assets; the age of the enterprise (age), measured by the difference between the current year and the year of listing; profitability (roa), measured by the net profit margin of total assets; the level of cash flow (cflow), measured by the ratio of net cash flow from operating activities to total liabilities; financial leverage (lev), measured by the asset–liability ratio; two positions together (dual), if the chairperson of the board of directors and the general manager are the same person, it is assigned a value of 1, and 0 otherwise; the value of the enterprise (tobin), measured using Tobin's Q; and the degree of concentration of shareholdings (top10), using the top ten shareholders to measure the proportion of the sum of the shareholding ratio. In addition, this article controls for corresponding variables at the city level. One is the city's level of economic development (pgdp), measured by the city's GDP per capita, and the other is the degree of government intervention (gov), measured by the share of the local government's fiscal expenditures in GDP.

3.2. Data sources and descriptive statistics

The research sample of this article is the A-share companies listed on the Shanghai and Shenzhen stock exchanges from 2007 to 2020. Financial and insurance industries and enterprises listed for less than three years are excluded. To overcome the influence of extreme values on the regression results, all continuous variables are winsored at the 1 % level on both sides. The financial data of the

Table 1
Definition of variables and descriptive statistics.

Variables	Variable Definition	Obs	Mean	Std. Dev.	Min	Max
Dinnov	Digital technology innovation	27,538	0.944	1.343	0	8.614
Policy	When a city is approved as a CBECPZ in the year of approval and thereafter, it takes 1, otherwise it takes 0.	27,538	0.241	0.428	0	1
size	Natural logarithm of total assets	27,514	22.038	1.558	16.009	31.138
age	Measure by the difference between the current year and the year of listing	27,538	7.735	6.479	4	30
roa	Net profit margin on total assets	27,536	0.04	0.689	−7.7	108.366
cflow	Net cash flows from operating activities to total liabilities	27,479	0.179	0.25	−0.145	33.929
lev	Asset-liability ratio	27,536	0.457	0.936	−0.195	96.959
dual	Whether the chairman and general manager are two positions in one	25,108	0.276	0.447	0	1
tobin	Corporate Growth	26,435	2.005	2.566	0.674	192.705
top10	Sum of shareholdings of top ten shareholders	25,922	30.252	23.462	0.002	101.16
pgdp	Natural logarithm of urban GDP per capita	27,505	11.147	0.76	7.727	13.056
gov	Government fiscal expenditure as a share of GDP	27,505	0.146	0.056	0.041	0.741

enterprises used in this article come from the CSMAR and WIND databases, the city-level data come from the corresponding year's China City Statistical Yearbook, and the patent data come from the China Research Data Service Platform (CNRDS) database. The descriptive statistics of the main variables are shown in Table 1, which indicates that there is a large gap in the output of digital technology patents among different enterprises.

4. Empirical results and analysis

4.1. Empirical results

4.1.1. Correlation analysis and VIF values

Before conducting the formal regression analysis, we first conducted a correlation analysis of the data to verify the relationships between the variables. Table 2 shows that there is a significant positive correlation between the core independent variable and the dependent variable at the 1 % level, which preliminarily verifies the hypothesis of this article. In addition, the VIF test values are all less than 10, indicating that there is no serious collinearity issue between variables.

Note: *, **, and *** indicate significance at the 10 %, 5 %, and 1 % significance levels, respectively.

4.1.2. Panel unit root testing

Because the data used in this article are short panel data with a large N and small T and because the vast majority of variables are at the enterprise level, the possibility of nonstationary data is relatively small. However, for the purpose of stability, we still conducted unit root tests on the data. Since the data in this article are unbalanced panel data, we chose the Fisher test, which is applicable to unbalanced panels, to test the unit root. The test results are shown in Table 3, and all variables are stationary, so the subsequent regression analysis can be conducted with confidence.

4.1.3. Baseline regression results

Table 4 reports the baseline results of the impact of the pilot policy on enterprise digital technology innovation. In particular, Column (1) presents the estimation results without controlling for fixed effects and without considering control variables, where the coefficient estimate of Policy is 0.465 and passes the significance test at the 1 % level. Column (2) presents the estimation results when controlling for industry, province, and time fixed effects. The coefficient estimate of Policy in this column is 0.175 and passes the significance test at the 1 % level. Column (3) presents the estimation results with the inclusion of firm-level control variables, where the coefficient estimate for Policy is 0.110 and passes the significance test at the 1 % level. Column (4) shows the estimation results after adding city-level control variables. Taking the estimation result in Column (4) as the basis, we find that compared with that of nonpilot cities, the digital technology innovation level of enterprises in pilot cities increases by approximately 9.5 % and passes the significance test at the 5 % level. This suggests that the pilot policy has significantly increased the level of digital technology innovation of enterprises.

4.2. Robustness tests

4.2.1. Parallel trends and dynamic effects tests

An important prerequisite for applying the asymptotic difference-in-differences method is to comply with the parallel trend assumption, i.e., without the policy influence of the CBECPZ policy, the trends of changes in the level of digital technology innovation of the enterprises in the treatment group and the control group should be parallel. This article draws on Beck et al. (2010) to replace $Post_t$ in the base regression Model (1) with a year dummy variable ($Year_t$). Considering that there are fewer data in the first 5 years and the last 4 years of the policy implementation, this article summarizes the data in the first 5 years of the policy implementation into the -5th period and the data in the last 4 years of the policy implementation into the 4th period. The rest of the variables are the same as in Equation (1). The specific model is constructed as follows.

$$Dinnov_{it} = \beta_0 + \sum_{t=-k}^{k} \delta_t Policy_{it} + \beta_2 Controls_{it+} Year + Prov + Industry + \varepsilon_{it} \quad (2)$$

$\sum_{t=-k}^{k} \delta_t Policy_{it}$ (k = −5, −3 ….., 4) represents the dummy variable for the ± k-th year from the approval of the CBECPZ. Specifically, when the experimental group cities are in the ± k-th year from the approval of the CBECPZ, the value is 1; otherwise, it is 0. To avoid multicollinearity, this article takes the sample starting year as the base period in the regression.

For clarity, the estimated coefficient δ_t of the cross term $Policy_{it}$ is depicted in Fig. 1. The solid dots in Fig. 1 portray the marginal effects of the CBECPZ, and the short vertical line represents the 95 % confidence interval. Fig. 1 shows that the coefficient estimates in the periods before the implementation of a CBECPZ are not significant, indicating that there is no significant difference between the treatment and control groups and that the research sample passes the parallel trend test. After the implementation of the pilot policy, except for the coefficient of the 0th period, which is not significant, the coefficients of the subsequent periods are significantly positive, and there is a certain time lag in the implementation effect of the policy. This indicates that the difference-in-differences method can be used to test the effect of the establishment of CBECPZs on the digital technology innovation of enterprises. This finding also verifies the basic conclusion of this article; that is, the establishment of CBECPZs has a positive long-term effect on enterprise digital technology

Table 2
Results of correlation analysis and VIF value.

	VIF	Dinnov	policy	size	age	roa	cflow	lev	tobin	dual	top10	pgdp	gov
Dinnov	–	1	1										
policy	–	0.151***											
size	1.5	0.173***	0.086***	1									
age	1.47	−0.00200	0.048***	0.380***	1								
roa	1.44	0	−0.011*	−0.030***	−0.0100	1							
cflow	1.43	0.028***	−0.037***	−0.266***	−0.264***	0.061***	1						
lev	1.39	−0.014**	−0.012*	0.079***	0.109***	−0.070***	−0.130***	1					
tobin	1.30	−0.019***	−0.011*	−0.243***	0.018***	0.444***	0.116***	−0.080***	1				
dual	1.16	0.060***	0.088***	−0.188***	−0.238***	0.014**	0.115***	−0.032***	0.046***	1			
top10	1.11	0.048***	0.074***	0.410***	0.399***	−0.00400	−0.235***	0.040***	0.046***	−0.160***	1		
pgdp	1.08	0.194***	0.509***	0.071***	−0.042***	−0.00400	0.034***	−0.032***	0.019***	0.144***	0.089***	1	
godv	1.07	0.035***	0.160***	0.159***	0.106***	−0.00700	−0.00800	−0.00900	0.014**	0.00300	0.118***	−0.013**	1

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% significance levels, respectively.

Table 3
Panel unit root testing.

Variable	Dinnov	Policy	Size	Roa	Cflow	Lev	Tobin	Dual	Top10	Pgdp	Gov
Fisher (ADF)	24.170 (0.000)	56.223 (0.000)	28.600 (0.000)	16.910 (0.000)	52.307 (0.000)	30.627 (0.000)	16.104 (0.000)	7.116 (0.000)	57.710 (0.000)	14.304 (0.000)	89.634 (0.000)
Fisher(PP)	170.194 (0.000)	170.060 (0.000)	88.410 (0.000)	148.635 (0.000)	228.246 (0.000)	111.758 (0.000)	119.068 (0.000)	59.094 (0.000)	94.175 (0.000)	40.225 (0.000)	8.751 (0.000)

Note: The null hypothesis of Fisher's test is that all panels contain unit root, the values in parentheses represent the significance level of the stationary test.

Table 4
Benchmark regression results.

Variables	(1)	(2)	(3)	(4)
	Enterprise digital technology innovation	Enterprise digital technology innovation	Enterprise digital technology innovation	Enterprise digital technology innovation
policy	0.465*** (0.031)	0.175*** (0.035)	0.110*** (0.039)	0.095** (0.037)
size			0.351*** (0.024)	0.350.026 (0.026)
age			−0.017*** (0.003)	−0.016 (0.003)
roa			−0.011 (0.017)	−0.011 (0.015)
cflow			0.113 (0.081)	0.085 (0.062)
leverage			−0.002 (0.010)	0.001 (0.008)
fix			−0.193 (0.138)	−0.227 (0.146)
tobin			0.012** (0.006)	0.011* (0.006)
dual			0.054 (0.034)	0.064* (0.037)
top10			0.001 (0.007)	0.001 (0.002)
lnpgdp				0.075 (0.046)
gov				−0.050 (0.432)
Observations	25,266	25,266	23,816	22,490
R-squared	0.022	0.236	0.351	0.355
Prov FE	NO	YES	YES	YES
Year FE	NO	YES	YES	YES
Industry FE	NO	YES	YES	YES

Note: Standard errors clustered at firm level are reported in parentheses, *, **, and *** indicate significance at the 10 %, 5 %, and 1 % significance levels, respectively.

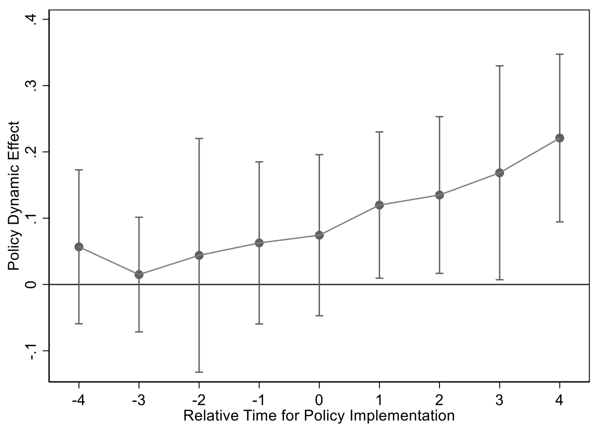

Fig. 1. Parallel trend test
Note: Solid dots denote the estimated coefficients δ_t of Eq. (2), and the short vertical lines are the upper and lower 95 % confidence intervals corresponding to the robust standard errors clustered to the city level.

innovation.

4.2.2. Placebo test

To avoid the effect of omitted or unobservable variables on the estimation results, this article conducts a placebo test. This article draws on the study of Li et al. (2021) to construct a placebo test for spurious policy shocks. Specifically, by randomly selecting the same number of cities as the real number of cities that have become CBECPZs as the treatment group, spurious policy dummy variables are generated to be included in the benchmark model for estimation. Theoretically, if the benchmark regression is not affected by omitted variables or other random factors, the estimated coefficients of the dummy policy variables should not be significantly different from zero; i.e., the randomly set up CBECPZ will not have a significant impact on the level of digital technology innovation of enterprises. In this article, the above process is repeated 500 times, and Fig. 2 plots the distribution of estimated coefficients after 500 regressions of the spurious policy dummy variables. The estimated coefficients are all very close to 0 and follow a normal distribution, while the estimated coefficients of Policy in the benchmark regression clearly fall outside this coefficient distribution. Therefore, the estimation results in this article are not affected by omitted variables or random factors, and the positive effect of the CBECPZ policy on enterprise digital technology innovation is robust.

4.2.3. Instrumental variables approach

Considering the possible problems of two-way causality and omitted variables in the baseline regression, this article draws on Nunn

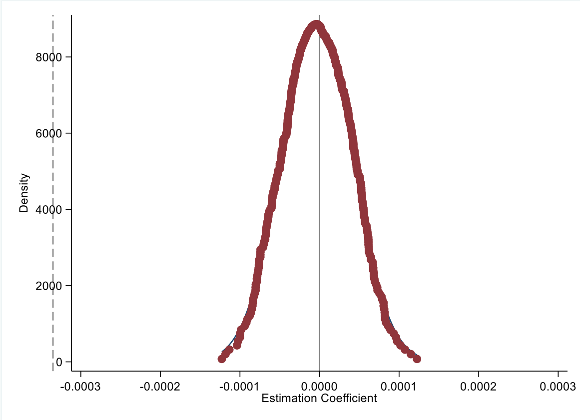

Fig. 2. Placebo test.

and Qian (2014), uses the product of the number of internet users in China in the previous year and the number of post offices per 100 people in 1984 as the instrumental variable,[1] and chooses the two-stage least squares (2SLS) method for the regression analysis. The specific results are shown in Table 5, where Columns (1) and (2) report the regression results for the instrumental variable (IV). The regression results show that there is a significant positive relationship between the instrumental variables and the pilot policy variables regardless of whether the control variables are included, and the validity of the instrumental variables in this article is verified by the weak instrumental variables test. Columns (3) and (4) report the 2SLS regression results, which show that the coefficients on the core explanatory variable Policy remain consistent with the baseline regression estimates regardless of the inclusion of control variables, thus confirming the robustness of the baseline regression model.

4.2.4. *Other robustness tests*

In addition to the tests conducted in the previous sections, several other robustness tests were also conducted in this study.

(1) **Replacing the explanatory variables.** First, the explanatory variable measures are replaced; digital technology patents are replaced with digital technology invention patents and digital technology utility model patents and re-estimated, and the results are shown in Columns (1) and (2) of Table 6. The establishment of CBECPZs significantly promotes the growth of digital technology invention patents, while there is no significant promotion effect on digital technology utility model patents. This indicates that the establishment of CBECPZs improves not only the quantity but also the quality of the digital technology innovation of enterprises.
(2) **PSM-DID estimation.** The Chinese government may prioritize some cities with a better foundation for cross-border e-commerce development in the selection of pilot cities, and this selection criterion may lead to biased estimation results. Therefore, this article further adopts the propensity score matching double difference method (PSM-DID) to overcome the selectivity bias problem. Specifically, whether or not a cross-border e-commerce pilot zone is used as the outcome variable, firm size, firm age, profitability, cash flow level, financial leverage, whether or not the two posts are combined, enterprise value, equity concentration, level of urban economic development, and level of government intervention are used as matching variables, and the cities in the treat and control groups are matched in accordance with near-neighbour matching in callipers. Based on the samples after propensity score matching, the regression test is rerun, and the test results are shown in Column (3) of Table 6. The regression coefficient of the CBECPZ (Policy) is significantly positive, which is consistent with the benchmark regression results.
(3) **Reanalyse the difference-in-differences variable.** When defining the policy shock dummy variable in the previous section, the year of policy implementation and the subsequent years are given values of 1. However, the period of policy implementation since the listing of cities was announced may be less than one year. Therefore, drawing on the practice of Lu et al. (2017), due to the establishment of the first batch of CBECPZs on March 7, 2015, this article sets the Post variable of the first batch of cities to 5/6 in 2015 to 1 in subsequent years; due to the establishment of the second batch of pilot zones in January 2016, this article sets it to 1 for the year of the implementation of the policy as well as for the subsequent years, and so on; for the third batch of pilot zones, Post is set as 1/2 in the year of implementation and 1 in the following years; in the fourth batch of cities, it is set as 1/12 in the year of implementation and 1 in the following years; and then the newly set Post and Treat are generated as the

[1] The main reasons for choosing this instrumental variable are as follows: (1) cross-border e-commerce is highly correlated with the logistics infrastructure, a high density of post offices implies that the logistics infrastructure of the area in the early years of the city is more complete and developed, and the cross-border logistics and express delivery industry is developed in areas with good logistics infrastructures, and cross-border e-commerce is developed better, so this instrumental variable satisfies the correlation condition. (2) The correlation between historical infrastructure and modern urban economic development is low, and the impact of traditional postal and telecommunications facilities on the level of urban green development is minimal, so this instrumental variable satisfies the exogeneity condition.

Table 5
Results of instrumental variable (IV) estimation.

Variables	(1)	(2)	(3)	(4)
	policy	policy	Dinnov	Dinnov
IV	2.67e-06 *** (1.21e-07)	2.07e-06*** (1.22e-07)		
Policy			0.461** (0.197)	0.658*** (0.210)
Control variable	NO	YES	NO	YES
Prov FE	YES	YES	YES	YES
Year FE				
Industry FE	YES	YES	YES	YES
Kleibergen-Paap rk LM statistic (P Value)	428.019 (0.000)	320.501 (0.000)		
Kleibergen-Paap Wald F statistic	486.852 [16.38]	287.418[16.38]		
R^2			−0.002	0.092
Observations	20,111	19,295	20,111	19,295

Note: Standard errors clustered at firm level are reported in parentheses, *, **, and *** indicate significance at the 10 %, 5 %, and 1 % significance levels, respectively. Critical values for the Stock-Yogo test at the 10 % level are in square brackets.

Table 6
Results of robustness test:variable replacement; PSM-DID; exclusion of other policy, etc.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Dependent variable replaced with patents for digital technology inventions	Dependent variable replaced with a digital utility patent	PSM-DID	Reanalyzing differential variables	Consideration of expected policy effects	Considering policy lag effects	Exclusion of other policy effects
Policy	0.099*** (0.032)	0.035 (0.030)	0.096*** (0.037)	0.084** (0.039)	0.102** (0.041)	−0.464*** (0.044)	0.096** (0.040)
Pilot cities × One year prior to policy implementation					0.036 (0.032)		
Control variable	YES	YES	YES	YES	YES	YES	YES
Bigdata							0.029 (0.044)
Freetrade							−0.039 (0.042)
Broadband							0.020 (0.046)
Prov FE	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES	YES
Observations	22,450	22,450	23,927	24,015	24,015	22,299	24,015
R-squared	0.334	0.312	0.105	0.102	0.358	0.355	0.358

Note: Standard errors clustered at firm level are reported in parentheses, *, **, and *** indicate significance at the 10 %, 5 %, and 1 % significance levels, respectively.

interaction terms, which are reintroduced into Model (1) for the regression. The regression results are reported in Column (4) of Table 6 and are generally consistent with the results of the baseline regression.

(4) **Consider the expected effects of the policy.** Considering that the expected response before the implementation of the policy will interfere with the assessment of the actual effect of the policy, this article adds the cross term of the pilot zone dummy variable and the year before the implementation of the policy dummy variable to the equation, and the results are shown in Column (5) of Table 6. The coefficient of the interaction term between the pilot zone and the year before the implementation of the policy is not significant, which indicates that there is no policy anticipation effect and that the CBECPZ policy has a strong exogenous nature.

(5) **Consider the lagged effect of the policy.** Considering that the CBECPZ pilot policy may not have an immediate impact on enterprises' digital technology innovation, this article lags one period of the core explanatory variables of the CBECPZ policy; at the same time, this article also lags one period of all the control variables to avoid bias from simultaneous equations, and the results are shown in Table 6, Column (6). The results show that the estimated coefficient of Policy is significantly positive, indicating that the CBECPZ pilot policy helps to improve the level of digital technology innovation of enterprises, supporting the previous conclusion.

(6) **Exclude other policy effects.** Considering that many similar or related policies between regions are implemented at the same time or with cross-purposes, it is clear that there is some policy stacking effect. Therefore, this article takes into account the fact that other policies with high relevance to enterprises' digital technology innovation were implemented during the sample

period, which may have had an impact on the regression results. To exclude the impact of other contemporaneous policies, this article controls for the national-level big data comprehensive pilot zone [43], free trade pilot zone pilot (Wang, 2021), and “Broadband China” pilot [44] policies on enterprises’ digital technology innovation. Specifically, this article adds the above three types of policy dummy variables to the baseline regression to examine the causal relationship between cross-border e-commerce pilot zones and enterprises’ digital technology innovation after controlling for other policy interferences. Big-data indicates whether the city belongs to the pilot city of the national big data comprehensive pilot zone in that year, and if it does, it takes a value of 1; otherwise, it takes a value of 0. Freetrade indicates whether the city belongs to the pilot city of the pilot free trade zone in that year, and if it does, it takes a value of 1; otherwise, it takes a value of 0. Broadband indicates whether the city belongs to the pilot city of “Broadband China” in that year, and if it does, it takes a value of 1; otherwise, it takes a value of 0. The estimation results after excluding the interference of these three policies are shown in Column (7) of Table 6, and all of the results show that after controlling for other policy shocks, the coefficient of Policy is still significantly positive, and the size of the coefficient does not change significantly from the baseline results, indicating that other policy shocks do not affect the causal relationship between cross-border e-commerce pilot zones and enterprises’ digital technology innovations, and the conclusions of the previous study still hold.

4.3. Heterogeneity test

4.3.1. Firm size heterogeneity

Different innovation resources and risk-bearing capabilities possessed by enterprises of different sizes will have different impacts on their digital technology innovations. Therefore, based on the benchmark model, the overall sample is divided into two subsamples of large-scale enterprises and small- and medium-scale enterprises according to the median business revenue of the enterprises to further investigate whether the CBECPZ will have heterogeneous effects on digital technology innovation for different types of enterprises. The estimation results are shown in Columns (1) and (2) of Table 7. After controlling for the three fixed effects simultaneously, the Policy coefficient is significantly positive for the sample of large-scale enterprises, while it is not significant for the sample of small- and medium-scale enterprises. This suggests that there is heterogeneity at the level of firm size attributes in the effect of the CBECPZ policy on digital technology innovation, which can significantly promote digital technology innovation in large-scale enterprises. The possible reason for this is that enterprises engaging in digital technology innovation activities are often accompanied by certain risks. Larger enterprises tend to be well funded and have greater bargaining power than upstream and downstream enterprises, so they usually have better resources and risk-bearing ability, and such enterprises have more advantages in carrying out digital technology innovation, whereas smaller enterprises, due to the lack of discursive power and control in the industry, cannot obtain timely commercial resources to help them realize their innovations, and it is difficult for them to obtain sustained financial support from banks and financial institutions. Therefore, the effect of digital technology innovation is greater for large enterprises than for small- and medium-sized enterprises.

4.3.2. Heterogeneity of enterprise ownership

The ownership attributes of enterprises usually have different impacts on their R&D investment and technology innovation. Therefore, here, the overall sample is divided into two subsamples of state-owned enterprises and nonstate-owned enterprises based on the baseline model to further examine whether the CBECPZ policy has heterogeneous effects on digital technology innovation for different types of enterprise ownership. The estimation results are shown in Columns (3) and (4) of Table 7. After controlling for the three fixed effects simultaneously, the Policy coefficient is significantly positive for the sample of nonstate-owned enterprises and nonsignificant for the sample of state-owned enterprises. This finding suggests that there is heterogeneity at the level of firm ownership attributes in the effect of the CBECPZ policy on digital technology innovation and that the CBECPZ policy can significantly promote digital technology innovation in nonstate-owned enterprises. The possible reasons for this are that nonstate-owned enterprises have

Table 7
Results of heterogeneity test.

Variables	Firm size heterogeneity		Heterogeneity of enterprise property rights		Industry heterogeneity		Heterogeneity of government resource allocation capacity	
	Large size enterprise	Small- medium size enterprise	State-owned ecterprise	Non-state enterprise	High ICT industry	Low ICT industry	High resource allocation capacity	Low resource allocation capacity
Policy	0.119** (0.053)	0.062 (0.046)	0.053 (0.071)	0.099** (0.043)	0.117** (0.050)	0.034 (0.049)	0.158*** (0.048)	0.048 (0.055)
Controls	YES	YES	YES	YES	YES	YES	YES	YES
Observations	12,641	11,369	9728	14,115	14,928	9082	10,349	13,662
R-squared	0.410	0.311	0.410	0.339	0.367	0.315	0.353	0.375
Prov FE	YES	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES	YES	YES

Note: Standard errors clustered at firm level are reported in parentheses, *, **, and *** indicate significance at the 10 %, 5 %, and 1 % significance levels, respectively.

more advantages in mobilizing resources in the process of cross-border e-commerce transformation, the application of digital technology can significantly improve the efficiency of processing information, further reducing the cost and risk of innovation, and cross-border e-commerce transformation can further enhance the confidence of investors, which is beneficial to nonstate-owned enterprises in easing the pressure of financing. While SOEs usually have more abundant talent reserves and resources, they are prone to internal problems such as redundant organizational structures and principal–agent problems. It is difficult for SOEs to transform their resource advantages into innovations to absorb the welfare effects of cross-border e-commerce transformation, and thus, they innovate less efficiently [45].

4.3.3. Industry heterogeneity

Based on the direct consumption coefficients of the core industries of the digital economy on each industry in the 2018 China input−output table, the ICT intensity (the degree of association with ICT) of the industry is calculated, and the mean value is used to classify each industry as a high ICT industry or low ICT industry so that the sample enterprises belonging to high ICT industries are categorized as the "high ICT industry" sample, and the sample enterprises belonging to low ICT industries are categorized as the "low ICT industry" sample. The regression results are shown in Columns (5) and (6) of Table 7. After controlling for the three fixed effects, the Policy coefficient is positive in the high ICT industry sample and insignificant in the low ICT sample. This suggests that there is heterogeneity at the level of the industry to which the enterprise belongs in the digital technology innovation effect of the CBECPZ policy on enterprises and that it can significantly promote the digital technology innovation of enterprises in industries with high ICT relevance. However, the effect on enterprises in industries with low ICT relevance is not significant.

4.3.4. Heterogeneity in government resource allocation capacity

Government resource allocation can effectively increase the tangible resources of enterprises, and the government's ability to allocate resources may significantly affect the relationship between cross-border e-commerce and enterprise innovation capacity. Therefore, this article measures the government's resource allocation capacity by the proportion of government financial expenditure to GDP and accordingly divides the locations of enterprises into cities with higher government resource allocation capacity and cities with lower allocation capacity. The results of the grouping test are reported in Columns (7) and (8) of Table 7. In cities with greater government resource allocation capacity, cross-border e-commerce development plays a significant role in promoting enterprises' digital technology innovation, while in cities with lower government allocation capacity, this promotion is not significant; i.e., a greater government resource allocation capacity can strengthen the role of cross-border e-commerce development in enhancing enterprises' digital innovation capacity.

4.4. Mechanism testing

In the mechanism test, existing studies generally use the mediated effect model for mechanism analysis, but the greatest drawback of the mediated effect model is that it cannot address the endogeneity problem of the regression of the explanatory variables on the mediating variables. Therefore, this article draws on the study of Ren et al. (2019) to directly regress the mechanism variables on the core explanatory variables and uses 2SLS for estimation to exclude the possible endogeneity problem of the mechanism test, and the mechanism test model in this article is set as follows:

$$Mech_{it} = \phi_0 + \phi_1 Policy_{it} + \gamma X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \tag{3}$$

In Equation (3), Policy is the estimation result of the regression model in the first stage of the instrumental variable test in the previous section, i.e., the prediction value obtained from the regression of the core explanatory variable Policy on the instrumental variable IV, and Mech is the mechanism variable, which indicates enterprise financing constraints, digital transformation, and producer service industry agglomeration. Drawing on Sun and Li [46], this article uses the ratio of corporate interest expenses to fixed assets to measure corporate financing constraints, and the larger the ratio is, the smaller the degree of corporate financing constraints. To make the estimation results more intuitively express the meaning of elevated financing constraints, this article uses the inverse of the ratio of corporate interest expenses to fixed assets and takes the logarithm (lnfincon) into the model for regression. A large value of this variable indicates that the degree of financing constraints of the enterprise is higher to ensure that the coefficient's meaning is concise and easy to understand.

For the measurement of enterprise digital transformation indicators, this article draws on existing practices in the literature [47] and employs Python to determine the frequency with which keyword word profiles appear in the annual reports of enterprises to portray the degree of enterprise digital transformation. This approach studies digital transformation as a continuous variable, which better reflects the differences in the degree of digital transformation of enterprises. Among the many word frequency extracts regarding digital transformation, Wu et al. [48] classified the word frequencies according to "ABCD"[2] technology use and technology practice application and constructed the most comprehensive word spectrum. Therefore, this article draws on the processing idea of Wu et al. [48], on the basis of obtaining specific keywords for digital transformation, based on Python's big data crawler function, all the texts in the annual reports of listed companies are captured and matched with the keywords, and the ratio of the number of times each keyword appeared in a specific year's annual report to the total number of words of the annual report is counted and then summed to obtain the

[2] ABCD refers to Artificial Intelligence, Blockchain, Cloud Computing, and Big Data.

total indicators of enterprises' digital transformation. In this article, the logarithm of this indicator is taken to obtain the final indicator of digital transformation (lndigital).

The agglomeration level of producer services (Aps) is measured by adopting the location entropy index by drawing on the study of Huang and Guo [49] with the following formula: $Aps_{it} = B_{it}/E_{it}/\sum_i B_{it}/\sum_i E_i$. where B_{it} is the number of employees in the producer services industry of city i in year t,[3] and E_i is the total number of employees in city i in year t. The other variables are the same as in Equation (1).

The results of the mechanism test are shown in Table 8. Columns (1) and (2) show the results of the test of enterprise financing constraints, and the results show that the policy dummy variable Policy is significant negative at the 1 % level regardless of whether or not the control variables are considered, indicating that the establishment of CBECPZs can effectively alleviate financing constraints and improve the ability of enterprises to increase financing, and the greater the enterprise financing capacity is, the more the enterprise can improve its digital technology innovation level [16]. Columns (3) and (4) report the test results of this impact mechanism of digital transformation. Regardless of whether the control variables are considered, the policy dummy variable Policy is significantly positive at the 1 % significance level, indicating that the establishment of CBECPZs significantly promotes the digital transformation of enterprises and improves the degree of their digital application, while some studies have shown that digital transformation promotes enterprise technology innovation [50]. In Columns (5) and (6), the results of this influence mechanism of producer service industry agglomeration are shown. Regardless of whether control variables are considered, the policy dummy variable Policy is significantly positive at the 1 % significance level, indicating that the establishment of CBECPZs significantly promotes regional productive service industry agglomeration, and studies have shown that producer service industry agglomeration promotes enterprise technology innovation [51]. In conclusion, the above results indicate that the establishment of CBECPZs improves enterprises' digital technology innovation capacity by alleviating their financing constraints and promoting the digital transformation and agglomeration of producer service industries.

5. Discussion

This article not only provides an empirical reference for evaluating the effect of cross-border e-commerce on digital technology innovation but also has significant policy implications for how the CBECPZ policy can better serve the innovation and development of foreign trade (Wu et al., 2023; [21]). The effect of cross-border e-commerce on enterprise digital technology innovation can be summarized as financing constraint alleviation brought about by policy superposition, digital transformation brought about by optimizing business processes, and producer service industry agglomeration brought about by upgrading trade models.

Regarding the financing constraint alleviation effect brought about by policy superposition, after the establishment of CBECPZs, the national and local governments will provide various fiscal support and tax subsidies to cross-border e-commerce enterprises. Moreover, due to the big data features of cross-border e-commerce, financial institutions can more accurately understand the development prospects of enterprises, conduct overall control of credit risks, and develop more precise financial support policies [31]. Regarding the digital transformation brought about by optimizing business processes, digital technologies such as big data, cloud computing, artificial intelligence, blockchain, and other digital technologies have comprehensively penetrated all aspects of the cross-border e-commerce industry and greatly promoted business process reengineering, thus resulting in digital transformation (Wu et al., 2024; Liu et al., 2024). Digital transformation enables them to fully utilize digital tools when identifying, absorbing, and utilizing external knowledge, empowering and enhancing their existing knowledge absorption capabilities through digital technology, and thus, improving the level of digital innovation (Lokuge et al., 2019; Yu et al., 2024). Regarding the producer service industry agglomeration brought about by upgrading trade models, cross-border e-commerce can drive the agglomeration of producer service industries, expand the coverage of the industrial chain, and accelerate the integration of upstream and downstream industries [18,40]. This provides convenient conditions for enterprises to share knowledge, technology, and processes; assists enterprises in reducing R&D innovation and production operation costs; provides greater economic space for digital technology research and innovation within enterprises [30,42,52]; and promotes enterprise digital technology innovation.

5.1. Conclusions

Based on micro data of Chinese listed companies from 2007 to 2020, this article starts from the unique perspective of the establishment of CPECPZs and uses the DID method to test the positive effect of cross-border e-commerce in promoting enterprise digital technology innovation. The results of this study revealed that enterprise digital technology innovation in pilot cities increased by approximately 9.5 % on average. The results of multiple robustness tests confirmed the robustness of the benchmark results.This effectively responds to the government original intention of the establishment of CPECPZs from a theoretical perspective, providing theoretical support for further deepening the construction of CPECPZs. Meanwhile, mechanism analysis shows that financing

[3] The producer service industry classification is mainly based on the Statistical Classification of Producer Service Industry (2019) issued by the National Bureau of Statistics, and at the same time, combined with the statistical calibre of China's cities, the transportation, warehousing, and postal service industry, the financial industry, the leasing and business service industry, the information transmission, computer service, and software industry, and the scientific research, technological service, and geological survey industry are selected as the representatives, and the relevant data on the number of employees are derived from the past years of the Chinese city. The relevant data on the number of employees are from the "China Urban Statistical Yearbook" of past years.

Table 8
Results of mechanism tests.

Variables	lnincon		lndigital		Aps	
	(1)	(2)	(3)	(4)	(5)	(6)
Policy	−0.131*** (0.038)	−0.067** (0.031)	0.186*** (0.033)	0.122*** (0.030)	0.149*** (0.007)	0.083*** (0.007)
Controls	NO	YES	NO	YES	YES	YES
Observations	23,362	22,077	23,226	22,089	20,528	19,370
R-squared	0.238	0.411	0.491	0.521	0.792	0.815
Prov FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES

Note: Standard errors clustered at firm level are reported in parentheses, *, **, and *** indicate significance at the 10 %, 5 %, and 1 % significance levels, respectively.

constraint alleviation, digital transformation, and producer service industry agglomeration are important mechanisms through which the CBECPZ policy affects enterprise digital technology innovation, effectively revealing the inherent mechanism by which cross-border e-commerce affects enterprise digital technology innovation. In addition, the heterogeneity test showed that the effect of the CBECPZ policy on enterprise digital technology innovation is greater among larger enterprises, nonstate-owned enterprises, industries with high ICT relevance, and cities with high government resource allocation capacity.

5.2. *Theoretical implications*

First, taking enterprises' digital innovation as the main research object, this article analyzed the digital innovation effect of cross-border e-commerce, aiming to provide a theoretical reference for how new trade formats can promote enterprises' digital innovation, expand the scope of evaluating the effectiveness of cross-border e-commerce reform policies, and provide new ideas for improving enterprises' digital innovation. Second, unlike previous studies that have focused mainly on the overall innovation effect of cross-border e-commerce, this article analyzed the enterprise digital technology effect of cross-border e-commerce and explored the mechanism behind it, expanding the theoretical analysis channels of trade innovation effects. Third, in terms of the research methods, this article took the establishment of CBECPZs in China as a quasinatural experiment and used a multi-period DID model to test the effect of cross-border e-commerce on enterprises' digital innovation, overcoming potential endogeneity issues in the evaluation process as much as possible.

5.3. *Practical implications*

First, policy-makers should continue to improve support policies for cross-border e-commerce, address deep-rooted contradictions and systemic problems with innovation, create a favourable environment for cross-border e-commerce development, improve the level of cross-border infrastructure and supporting services, and promote the high-quality development of cross-border e-commerce, which will ultimately contribute to the improvement of enterprise digital technology innovation. Second, preferential policies should be formulated to enhance the leading role of the CBECPZ policy in the digital technology innovation of smaller enterprises, state-owned enterprises, industries with lower ICT relevance, and regions where the government has a poorer ability to allocate resources. These enterprises, industries and regions should receive greater support in terms of capital and talent introduction. Third, the cities where the pilot zones are located should respect the rules of the market, give full play to the fundamental role of the market in resource allocation, taper off unnecessary blind interventions, improve the efficiency of resource allocation, and allocate more resources to enterprise digital technology innovation.

5.4. *Limitations and future research*

The first limitation is the data interval. Due to data availability, the data in this article are available only up to 2020. Thus, we cannot capture the policy effects of the last three batches of CBECPZs. In the future, with the updating of the data, the sample period can be extended to after 2020 to capture the effects of the last three batches of CBECPZs. The second limitation is the research method. This article mainly uses DID and instrumental variable methods to avoid the estimation bias caused by endogeneity problems, but estimation errors caused by spatial correlation cannot be ruled out. Therefore, spatial econometric methods can be used to exclude spatial correlation and test spatial spillover effects and siphon effects to obtain more accurate estimation results in the future. The third limitation is the research perspective; this article only explores the effects of cross-border e-commerce on enterprises' digital innovation. In the future, the research perspective can be further expanded to other areas, such as enterprise digital transformation, city entrepreneurship, and green development.

Data availability statement

Data will be made available on https://doi.org/10.6084/m9.figshare.25997254.

CRediT authorship contribution statement

Kejie Chen: Conceptualization. **Shiwen Luo:** Data curation. **David Yoon Kin tong:** Methodology.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] Y. Qi, T. Shen, Achievements, experience, and prospects of digital technology innovation in China since the 18th National Congress of the Communist Party of China, Study & Exploration 333 (4) (2023) 76–87.
[2] F. Tao, P. Zhu, C. Qiu, X. Wang, The impact of digital technology innovation on enterprise market value, Journal of Quantitative & Technological Economics 40 (5) (2023) 1–24.
[3] Y. Qi, B. Du, X. Wen, Mission embeddedness and pattern selection of digital strategic transformation of SOEs: a case study based on the typical practice of digitalization in three central enterprises, Journal of Management World 37 (11) (2021) 137–158.
[4] S. Firk, Y. Gehrke, A. Hanelt, M. Wolff, Top management team characteristics and digital innovation: exploring digital knowledge and TMT interfaces, Long. Range Plan. 55 (3) (2022) 102166.
[5] N. Chen, Analysis of the correlation between cross-border E-commerce and economic growth based on hierarchical multilevel gray evaluation model, J. Math. 2022 (2022) 1–10.
[6] Y. Wang, Y. Wang, S.H. Lee, The effect of cross-border e-commerce on China's international trade: an empirical study based on transaction cost analysis, Sustainability 9 (11) (2017) 2028.
[7] S. Ma, X. Guo, H. Zhang, New driving force for China's import growth: assessing the role of cross-border e-commerce, World Econ. 44 (12) (2021) 3674–3706.
[8] T.Y. Kim, R. Dekker, C. Heij, Cross-border electronic commerce: distance effects and express delivery in European Union markets, Int. J. Electron. Commer. 21 (2) (2017) 184–218.
[9] Z.H. Yin, C.H. Choi, The effects of China's cross-border e-commerce on its exports: a comparative analysis of goods and services trade, Electron. Commer. Res. 23 (1) (2023) 443–474.
[10] S.Z. Ma, J.W. Guo, H.S. Zhang, The trade cost reduction effect of cross-border e-commerce: mechanism and empirical evidence, International Economics and Trade Research 35 (5) (2019) 69–85.
[11] Q.Y. Ju, X.K. Zhao, B.W. Sun, Internet and trade costs: an empirical analysis based on cross-border e-commerce data from China SME exports, China Ind. Econ 55 (2020) 181–196.
[12] M. Falk, E. Hagsten, E-commerce trends and impacts across Europe, Int. J. Prod. Econ. 170 (2015) 357–369.
[13] A. Lendle, P.L. Vézina, Internet Technology and the Extensive Margin of Trade: Evidence from e B ay in Emerging Economies, Rev. Dev. Econ. 19 (2) (2015) 375–386.
[14] F. Cassia, F. Magno, Cross-border e-commerce as a foreign market entry mode among SMEs: the relationship between export capabilities and performance, Review of International Business and Strategy 32 (2) (2022) 267–283.
[15] M. Zhong, Z. Wang, X. Ge, Does cross-border e-commerce promote economic growth? empirical research on China's Pilot Zones, Sustainability 14 (17) (2022) 11032.
[16] Y. Yang, N. Chen, H. Chen, The digital platform, enterprise digital transformation, and enterprise performance of cross-border E-commerce—from the perspective of digital transformation and data elements, Journal of Theoretical and Applied Electronic Commerce Research 18 (2) (2023) 777–794.
[17] B.C. Xu, H. Li, Y.M. Guo, A study on the economic driving effect of inbound tourism by the establishment of cross-border e-commerce comprehensive pilot zones: a quasi-natural experiment, J. Nat. Resour. 38 (11) (2023) 2899–2918.
[18] Y.R. Liu, L. Yang, Z.B. Liu, Cross-border E-commerce and producer services agglomeration, Journal of World Economy 3 (2023) 63–93.
[19] B. Dai, S. Min, Can Cross-border E-commerce reform reduce supply chain risks? Quasi-natural experiment based on Cross-border E-commerce comprehensive pilot zone, Journal of the Knowledge Economy (2023) 1–29.
[20] Q. Yuan, Y. Ji, W. Zhang, T. Lei, Cross-border E-commerce and urban entrepreneurial vitality-A quasi-natural experiment evidence from China, Sustainability 16 (5) (2024) 1802.
[21] Y. Li, Z. Zheng, M. Zhao, Z. Liu, How does digital trade impact urban carbon emissions efficiency? Evidence from China's cross-border e-commerce pilot zones, J. Clean. Prod. 456 (2024) 142363.
[22] J. Lyu, China cross-border e-commerce comprehensive pilot zone and urban residents' tourism consumption: empirical study based on CHFS data, Finance Res. Lett. 64 (2024) 105396.
[23] Y. Song, H. Hu, Research on the impact and mechanism of cross-border E-commerce reform on the export of enterprises in the pilot zone, Journal of Modern Finance and Economics 387 (35) (2022) 20–35.
[24] H. Hu, Y. Song, Establishment of cross-border E-commerce pilot zone and enterprise risk-taking, Journal of Zhongnan University of Economics and Law 253 (4) (2022) 16–53.
[25] H. Zhang, Y. Xie, G. Yao, Institutional opening up and consumer welfare enhancement:based on the evidence of cross-border E-commerce comprehensive pilot zones, Econ. Res. J. 58 (8) (2023) 155–173.
[26] Y. Ning, Y. Ma, N. Meng, Does the cross-border E-commerce improve the firm innovation? Journal of Zhongnan University of Economics and Law 258 (3) (2023) 83–93.
[27] Y. Shi, J. Yu, Cross-border E-commerce reform and enterprise innovation-Based on a quasi-natural experiment of the establishment of Cross-border E-commerce integrated pilot zones, Journal of International Trade Problem 4 (2023) 37–55.
[28] B.H. Hall, Pietro Moncada-Paternò-Castello, S. Montresor, A. Vezzani, Financing constraints, r&d investments and innovative performances: new empirical evidence at the firm level for europe, Econ. Innovat. N. Technol. 25 (3) (2015) 1–14.
[29] P.F. Peretto, S. Valente, Growth on a finite planet: resources, technology and population in the long run, J. Econ. Growth 20 (3) (2015) 305–331.
[30] D. Peng, E. Elahi, Z. Khalid, Producer service agglomeration, human capital level, and urban economic performance, Sustainability 15 (9) (2023) 7051.
[31] X. Zhang, D. Xu, L. Xiao, Intelligent perception system of big data decision in cross-border e-commerce based on data fusion, J. Sens. 2021 (2021) 1–11.
[32] A.P. Alekseenko, Legal regulation of China's cross-border E-commerce comprehensive Pilot areas: a Russian perspective, China and WTO Review 8 (1) (2022) 7–28.
[33] W.T. Wang, X.H. Li, Y. Lu, Tax reduction incentives and corporate debt burden - evidence from the policy of halving income tax for small and micro enterprises, Econ. Res. 8 (2020) 105–120.
[34] O. Henfridsson, L. Mathiassen, F. Svahn, Managing technological change in the digital age: the role of architectural frames, J. Inf. Technol. 29 (2014) 27–43.
[35] C. Loebbecke, A. Picot, Reflections on societal and business model transformation arising from digitization and big data analytics: a research agenda, J. Strat. Inf. Syst. 24 (3) (2015) 149–157.
[36] G.B. Shen, Z.Y. Yuan, The impact of corporate internetization on Chinese corporate innovation and export, Econ. Res. 55 (1) (2020) 33–48.

[37] Huang Xianhai, Wang Fang, Yang Gaoju, Firm digital transformation and innovation:from the perspective of network spillover, Economic Theory and Business Management 43 (11) (2023) 56–69.
[38] K. Drechsler, R. Gregory, H.T. Wagner, S. Tumbas, At the crossroads between digital innovation and digital transformation, Commun. Assoc. Inf. Syst. 47 (1) (2020) 521–538.
[39] C.I. Jones, C. Tonetti, Nonrivalry and the economics of data, Am. Econ. Rev. 110 (9) (2020) 2819–2858.
[40] C. Wang, Analyzing the effects of cross-border E-commerce industry transfer using big data, Mobile Inf. Syst. 2021 (2021) 1–12.
[41] S.R. Samanta, J. Gochhayat, P.K. Mallick, B.K. Mishra, Sustainability and Equity: Economic Democracy and Social Empowerment, Global Knowledge. novapublishers, 2024.
[42] R. Kharb, V. Suneja, S. Aggarwal, P. Singh, U. Shahzad, N. Saini, D. Kumar, The Relationship between investment determinants and environmental sustainability: evidence through meta-analysis, Q. Rev. Econ. Finance 94 (2024) 267–280.
[43] Y. Ren, X. Zhang, H. Chen, The impact of new energy enterprises' digital transformation on their total factor productivity: empirical evidence from China, Sustainability 14 (21) (2022) 13928.
[44] Y. Zhu, Digital economy, enterprise financing and innovation: a quasi-natural experiment of "Broadband China" pilot policy. Highlights in Business, Econ. Manag. 9 (2023) 212–221.
[45] X. Dong, J. Zhao, P. Yuan, Research on innovation efficiency loss of state-owned enterprises, China Industrial Economics 2 (2014) 97–105.
[46] L.Y. Sun, R.L. Li, Do financing constraints limit Chinese firms' export participation? Economics 11 (1) (2012) 231–252.
[47] C. Zhao, W. Wang, X. Li, How does digital transformation affect the total factor productivity of enterprises, Finance and Trade Economy 42 (7) (2021) 114–129.
[48] F. Wu, H. Hu, H. Lin, X. Ren, Enterprise digital transformation and capital market performance: empirical evidence from stock liquidity, Manag. World 37 (7) (2021) 130–144.
[49] F.H. Huang, W.J. Guo, Producer service industry agglomeration and economic growth efficiency of the Yangtze River Delta city cluster under the perspective of spatial spillover, Statistical Research 37 (7) (2020) 66–79.
[50] X. Zhao, X. Sun, L. Zhao, Y. Xing, Can the digital transformation of manufacturing enterprises promote enterprise innovation? Bus. Process Manag. J. 28 (4) (2022) 960–982.
[51] X. Guo, K. Guo, H. Zheng, Industrial agglomeration and enterprise innovation sustainability: empirical evidence from the Chinese A-share market, Sustainability 15 (15) (2023) 11660.
[52] M. Eswaran, A. Kotwal, The role of the service sector in the process of industrialization, J. Dev. Econ. 68 (2) (2002) 401–420.