Heterogeneous Impact of Regional E-Commerce Development on Technological Innovation: An Empirical Analysis Based on China's Interprovincial Panel Data

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Abstract: In today's booming development of e-commerce and the continuous display of national technological innovation level, the impact of e-commerce and technological innovation is receiving increasing attention. However, the question of whether e-commerce development has a promoting effect on technological innovation rather than structural optimization still needs to be explored. Based on China's provincial panel data from 2013 to 2021, this paper constructs a measurement system of e-commerce development level and a measurement function of technological innovation level through comprehensive analysis and entropy weight method, and uses a fixed effect model to explore the impact of e-commerce development on technological innovation. Research has found that the development of e-commerce has an extremely significant positive impact on technological innovation, and the development of e-commerce will promote the improvement of technological innovation level. Through heterogeneity analysis, it can be concluded that the development of e-commerce has an extremely significant positive impact on technological innovation in North China, Northeast China, East China, and Northwest China, with the largest impact on Northwest China, followed by East China and Northeast China, and the smallest impact on North China; The development of e-commerce has no significant impact on technological innovation in Central China, South China, and Southwest China

Keywords: E-Commerce Development; Technological Innovation; Regional Heterogeneity; Comprehensive Evaluation Method; Entropy Weight Method; Fixed Effects Model

1. Introduction

According to data from the National Bureau of Statistics, China's innovation output index reached 353.6 in 2021, marking a 10.6% increase from the previous year. The number of domestic patent grants surged by 26.9% to 4.467 million, while technology maket transaction contracts totaled 3.72943 trillion yuan – a 32% year-on-year growth. These figures demonstrate accelerating technology transfer and commercialization processes. The country's innovation ecosystem has achieved remarkable progress: abundant research outputs, expanding technology markets, accelerated innovation development, significantly optimized innovation environment, steadily increasing R&D investment, rapid output growth, and increasingly evident innovation outcomes. By the end of 2022, China had become the world leader in valid invention patents.

Meanwhile, with the continuous advancement of internet technology and the proliferation of mobile devices, coupled with a supply-demand imbalance in diverse product categories, China's e-commerce has permeated all industries. According to the "China E-Commerce Report," the country's e-commerce transaction volume reached 42.3 trillion yuan, up 19.6% year-on-year; online retail sales hit 13.1 trillion yuan, growing 14.1%; physical goods sold online amounted to 10.8 trillion yuan, accounting for 24.5% of total retail sales of consumer goods; cross-border e-commerce imports and exports surged nearly tenfold over five years to 1.92 trillion yuan. The e-commerce sector has created and supported employment for over 67 million people, maintaining its position as the world's largest online retail market for nine consecutive years. Beyond driving rapid economic growth, e-commerce has demonstrated significant impacts in other areas. Research by Zhao Xiaojun shows it promotes industrial upgrading and tertiary sector transformation [1], while also narrowing urban-rural income gaps [2] and accelerating corporate transformation [3]—arguments supported by extensive literature. However, the relationship between industrial upgrading, enterprise transformation involving resource restructuring—— (through optimizing resource allocation, industrial clusters, and high-tech sectors [4]), and e-commerce innovation remains underexplored. Whether e-commerce directly or indirectly drives technological innovation, increases output, and enhances quality still requires further investigation. Based on this starting point, this paper will use the inter-provincial panel data of China from 2013 to 2021 to empirically demonstrate the impact degree of e-commerce development on technological innovation, so as to provide reference for promoting the development of technological innovation. In addition, this paper will also deeply discuss the regional heterogeneity of this impact, so as to provide more targeted policy measures.

2. Literature Review

In recent years, e-commerce and technological innovation have become hot words on the Internet. People are paying more and more attention to the development and role of the two, and many experts and scholars have also conducted relevant researches on this. This paper sorts out some academic research results related to the development of e-commerce and technological innovation level, so as to provide ideas for the subsequent research.

Research on the development of e-commerce and its measurement standards dates back nearly three decades. When the internet first entered China, scholars and experts began examining global and domestic e-commerce trends. Since 2013, research on e-commerce has surged exponentially. Nie, then Deputy Director of the E-Commerce and Informatization Department at the Ministry of Commerce, noted that e-commerce, as a new business model, is rapidly integrating with the real economy. This convergence will profoundly impact daily production, living, and consumption patterns, while becoming a crucial resource allocation mechanism under conditions of informatization, networking, marketization, and globalization. It has emerged as a key driver of socioeconomic progress. Numerous domestic and international scholars have validated e-commerce's role in economic development [5-7]. In recent years, numerous scholars and experts have conducted extensive research on the impact of e-commerce development. Zeng [8] proposed that e-commerce would foster new service business models and drive the transformation and upgrading of the service industry. Dong demonstrated through empirical analysis that e-commerce development significantly enhances export complexity [9]. Liargued that the synergistic development between e-commerce and urban commerce could boost regional commercial vitality in neighboring areas [10]. Zhao analyzed the heterogeneous effects of e-commerce development on indutrial structure upgrading, concluding that while it promotes industrial sophistication, it shows no significant impact on rationalization [1]. Regarding measurement methods for e-commerce development levels, different researchers adopted distinct approaches. Hao directly referenced the Alibaba E-commerce Development Index, which includes two key metrics: online merchant index and online shopping index [11]. Yao employed a comprehensive analysis method to calculate regional e-commerce development indices, using Analytic Hierarchy Process (AHP) for indicator weighting [12]. Jia applied factor analysis to assess the integration level of urban-rural commercial circulation [13]. Zhang combined AHP with weighting methods and a comprehensive evaluation model to evaluate digital agriculture development across 31 Chinese provinces from 2015 to 2019 [14].

Regarding research on technological innovation, it serves as a crucial tool for China to drive economic development and enhance global competitiveness. This approach plays a vital role in industrial upgrading, economic restructuring, innovation-driven growth, boosting corporate market competitiveness and profitability, as well as advancing social progress and human civilization. Jiang & Zhou [15] measured technological innovation levels using the logarithm of patent grants. Lei [16] evaluated regional technological innovation through patent grants in circulation industries versus national totals, demonstrating that digital finance creates dual threshold effects in driving green total factor productivity improvements in circulation sectors. Su & Liu [17] assessed regional innovation levels via the ratio of patent applications to population size, revealing significant dual threshold effects of technological innovation in enhancing logistics efficiency and modern service industry development. Drawing from extensive literature, experts have reached a consensus on using patent-related metrics to measure technological innovation levels.

As mentioned above, numerous studies have been conducted on the impact of e-commerce and technological innovation, with many papers related to both. Chen Lin [18] used a multiple regression model to demonstrate the positive influence of digital finance on technological innovation, along with the positive moderating effect of property rights characteristics. The study measured technological innovation levels through the natural logarithm of R&D investment amounts. Lu [19] analyzed that e-commerce development can promote innovation activities in commercial circulation enterprises, while economic policy uncertainty exerts a positive moderating effect during this process. Tian [20] discussed how the digital economy facilitates corporate innovation, and further revealed that the digital economy promotes innovation through mediating mechanisms such as human capital effects and market demand orientation. However, these studies either lack comprehensive and accurate measurements of e-commerce development levels, employ overly simplistic indicators for technological innovation assessment, or impose strict limitations on technological innovation and e-commerce development—such as narrowing e-commerce to the digital economy, online shopping, or digital finance, and reducing technological innovation to enterprise innovation or innovation investment—which fail to accurately reflect their respective levels and relationships. Therefore, this paper combines the literature review and theoretical analysis to conduct relevant research on e-commerce development and technological innovation.

3. Theoretical Analysis and Hypothesis Formulation

This paper argues that e-commerce has dismantled traditional barriers and overcome the geographical limitations of conventional business models. By connecting merchants with consumers through the internet, it has enabled globalized sales and transactions. This globalized business model allows both businesses and consumers to more flexibly choose sales channels, operational scopes, and purchasing options, while also fostering technological exchange and innovation. Furthermore, the development of e-commerce has driven advancements in information technology. The growth of e-commerce requires robust IT infrastructure, and its rapid expansion has accelerated technological upgrades and applications [21]. For instance, e-commerce has spurred innovations in payment technologies—from Alipay and WeChat Pay to emerging solutions like blockchain—providing more secure payment options. Simultaneously, the application of big data technology in e-commerce creates new opportunities and scenarios. Through analyzing consumer behavior, product information, and transaction data, e-commerce companies gain more accurate market insights and predictive capabilities, enhancing their competitiveness. Consequently, the evolution of e-commerce also propels IT progress [22]. Technologies such as electronic payments, digital contracts, and digital signatures provide technical support for e-commerce development. Moreover, e-commerce drives advancements in logistics and supply chain management, with innovations in these fields further catalyzing its growth. Finally, the development of e-commerce has driven business model innovation, which in turn promotes technological advancement. For instance, the emergence of O2O (Online-to-Offline) models has enhanced offline-to-online interactions, requiring more advanced technical support. Moreover, the rapid growth of e-commerce has accelerated the adoption and upgrading of internet technologies. Through digital platforms, consumers and businesses can conduct distance-free transactions, improving sales channels and operational efficiency while creating more commercial opportunities for internet applications. Therefore, e-commerce not only drives business model innovation but also fuels technological progress. In summary, the development of e-commerce has facilitated the application and evolution of information technology, network technology, artificial intelligence, and IoT, providing broader application scenarios and business opportunities for technological innovation. Simultaneously, technological innovation offers stronger support and impetus for e-commerce, with both sectors mutually reinforcing each other [23], collectively driving China's economic development and transformation.

Based on the above theory, this paper puts forward a hypothesis that the development of e-commerce will promote technological innovation.

This hypothesis posits that e-commerce, as a novel business model and production method, has profoundly influenced technological innovation. Supported by information technology, network technology, artificial intelligence, and the Internet of Things (IoT), e-commerce's rapid development has accelerated the application and advancement of these technologies. Simultaneously, it provides broader application scenarios and commercial opportunities for these technologies, driving their innovation and upgrades. Therefore, we can conclude that the growth of e-commerce effectively promotes technological innovation.

4. Research Design

4.1 Core explanatory Variables

4.1.1 Construction of evaluation system for development level of e-commerce

The dependent variable in this study is the regional e-commerce development level. Following the framework established by Yao [12] and Zhang [14], we developed a measurement system for regional e-commerce development through four sub-branches: e-commerce transaction volume, informatization level, e-commerce human capital level, and e-commerce development environment. The four key indicators for measuring regional e-commerce transaction volume include: the proportion of e-commerce sales in GDP (POS), the ratio of e-commerce sales to population (ASQ), the proportion of e-commerce Procurement in GDP (POP), and the ratio of e-commerce procurement to population (APQ). For informatization level, we measured the ratio of investment in information transmission, computer services, and software industries to total fixed asset investment (IOW), the number of domain names registered under China's CN system (NOD), and the number of websites (NOW). Human capital level was assessed by the proportion of e-commerce practitioners (EPR), internet penetration rate (IPR), and wages of e-commerce workers (EPS). Development environment level was evaluated through the number of e-commerce industrial parks (NOI), the number of e-commerce enterprises (NOE), and the proportion of e-commerce transaction activities (POA). The indicator structure is detailed in Table 1.

Table 1. Design of Measurement Indicators for E-Commerce Development Level

	First-level indicators	Secondary indicators	data code
The level of e-commerce development	E-commerce transaction level	The share of e-commerce sales in GDP	POS
		E-commerce sales to population ratio	ASQ
		The proportion of e-commerce purchases in GDP	POP
		E-commerce purchase volume to population ratio	APQ
	Level of informatization	The ratio of investment in information transmission, computer services and software industry to total fixed asset investment	IOW
		Number of domain names registered under Cn (10,000)	NOD
		Number of websites (10,000)	NOW
	Level of human capital in e-commerce	The proportion of e-commerce practitioners	EPR
		Internet penetration rate	IPR
		The salary level of e-commerce practitioners	EPS
	The level of e-commerce development environment	Number of e-commerce industrial parks	NOI
		Number of e-commerce enterprises	NOE
		The proportion of e-commerce transaction enterprise activities	POA

Since this paper uniformly selects panel data with reliable data sources, and the data requirements are complete, accurate and continuous, but there is a lack of official or authoritative statistical data on the number of e-commerce parks (NOI) in each provincial region, this paper excludes this indicator for the sake of rigor.

The dataset was transformed into panel data. A linear interpolation method (i-processing, same below) was applied to handle minor missing values, with negative interpolated values assigned 0. Standardization (z-processing) was performed on the remaining 12 indicators in Table 2. Multicollinearity refers to linear relationships among independent variables, where one variable can be a linear combination of others. When multicollinearity exists, the model becomes non-invertible when calculating partial regression coefficients. Key manifestations include: inconsistent results between overall model variance analysis and individual variable coefficient tests; statistically significant variables appearing insignificant by professional judgment; and coefficients or signs severely deviating from actual conditions. Common testing methods include Tolerance (T) and Variance Inflation Factor (VIF). The most widely used VIF is calculated using the formula (1):

$$\mathrm{VIF}=\frac{1}{1-R_i^2} \tag{1}$$

Table 2. Correlation Analysis between Design Index Variables

Variable	VIF	1/VIF
APQ	174.2	0.00574
ASQ	151.1	0.00662
POP	48.46	0.0206
POS	39.32	0.0254
EPR	14.42	0.0693
NOW	7.590	0.132
EPS	4.560	0.219
NOE	4.080	0.245
IPR	2.880	0.348
NOD	2.780	0.359
POA	2.360	0.423
Mean	VIF	41.06

Table 3. Correlation Analysis between Excluded Index Variables

Variable	VIF	1/VIF
POS	4.060	0.246
EPS	3.790	0.264
NOW	3.150	0.317
IPR	3.070	0.325
NOD	2.670	0.375
NOE	2.640	0.379
IOW	1.930	0.517
POA	1.870	0.534
Mean	VIF	2.900

The VIF value is greater than 1. The closer the VIF value is to 1, the less severe the multicollinearity, and conversely, the more severe it becomes. When multicollinearity is significant, appropriate adjustment methods should be implemented. The tolerance coefficient ranges between 0 and 1. A low tolerance coefficient indicates collinearity between this independent variable and other independent variables. If the regression coefficient estimate for this tolerance coefficient lacks stability, the calculated regression coefficients will also exhibit substantial errors. The variance inflation coefficient is the reciprocal of the tolerance coefficient. A larger VIF value signifies lower tolerance coefficients for the independent variable, indicating stronger collinearity issues. Therefore, we conducted VIF tests on these indicators, with results shown in Table 2. Indicators with VIF values exceeding 10 were selected and removed. After removal, all remaining indicators showed VIF values below 5 (as shown in Table 3), confirming that no severe multicollinearity existed among the retained indicators [24].

After processing, the measurement system of e-commerce development level is shown in Table 4.

Extract the processed values of secondary indicators from Table 3 and calculate their weights using the entropy weighting method. According to the fundamental principles of information theory, information measures the orderliness of a system, while entropy quantifies its disorder. The definition of information entropy indicates that for any indicator, its entropy value reflects the dispersion level: lower entropy values indicate greater dispersion, thereby enhancing the indicator's influence (weight) in comprehensive evaluation. Indicators with identical values become irrelevant in such evaluations. Therefore, information entropy serves as a tool to determine weights for multi-criteria assessments. As an objective weighting method, the entropy weighting process involves three steps: First, construct judgment matrices for each year's evaluation indicators; second, normalize these matrices to obtain normalized judgment matrices; Third, calculate entropy values for each indicator based on its definition. After defining the n-th indicator's entropy, derive its corresponding entropy weight. Finally, compute the overall system weights as shown in Table 5. In this table, ej represents the entropy value of the corresponding indicator (higher values indicate lower information content), while gij denotes the information utility value. By normalizing these values to obtain entropy weights W, the combined entropy weights W_i are calculated by summing the entropy weights of all secondary indicators.

Table 4. Measurement System of E-Commerce Development Level after Optimization

	First-level indicators	Secondary indicators	data code
The level of e-commerce development	E-commerce transaction level	The share of e-commerce sales in GDP	POS
	Level of informatization	The ratio of investment in information transmission, computer services and software industry to total fixed asset investment	IOW
		Number of domain names registered under Cn (10,000)	NOD
		Number of websites (10,000)	NOW
	Level of human capital in e-commerce	Internet penetration rate	IPR
		The salary level of e-commerce practitioners	EPS
	The level of e-commerce development environment	Number of e-commerce enterprises	NOE
		The proportion of e-commerce transaction enterprise activities	POA

Table 5. Weight of E-Commerce Development Level Indicators

K value: 0.177582	Level of informatization			E-commerce transaction level	The level of e-commerce development environment		Level of human capital in e-commerce	
	IOW	NOD	NOW	POS	NOE	POA	EPS	IPR
ej	0.986	0.996	0.791	0.936	0.905	0.993	0.963	0.976
gij	0.014	0.004	0.209	0.064	0.095	0.007	0.037	0.024
W	0.030	0.009	0.462	0.141	0.209	0.015	0.081	0.053
W close	0.501			0.141	0.224		0.133	

As shown in Table 5, all four primary indicators used to measure e-commerce development levels have weights exceeding 5%, confirming their validity as assessment metrics. The informatization level carries the highest weight of 0.501, highlighting its critical influence on e-commerce development. Other key indicators—e-commerce transactions, development environment, and human capital—have weights above 0.05 at 0.141, 0.224, and 0.133 respectively, indicating their combined impact on e-commerce growth. This demonstrates that informatization significantly drives e-commerce development, aligning with Hao Feilong's (2016) [11] findings and validating the rationality of our measurement framework.

The measurement index of e-commerce development level is obtained by normalizing the weights of each index in Table 5 and the corresponding values, and the calculation formula is as follows (2)

"X=0.030*IOW+0.009*NOD+0.462*NOW+0.141*POS+0.209*NOE+0.015*POA+0.081*EPS+0.053*IPR" (2)

According to the above formula, the e-commerce development level of China (as shown in Figure 1) and 31 provincial administrative regions (see Schedule 1) are obtained.

4.1.2 Analysis of the current situation of E-commerce development in China

As shown in Figure 1, China's E-commerce Development Level Index increased from 2.279835 in 2013 to 6.262530 in 2021, more than doubling. This demonstrates the sustained rapid growth of China's e-commerce market, which has become the most vital and dynamic sector in the country. From 2013 to 2016, the growth rate of China's e-commerce continued to rise, increasing from 2.28% in 2013 to 4.23% in 2016. However, after 2016, the growth rate began to slow down, possibly due to market saturation and intensified industry competition. The pandemic significantly accelerated China's e-commerce growth in 2020, reaching a growth rate of 5.67%, indicating that the pandemic influenced consumer purchasing behavior, leading them to shift towards online shopping. This reflects that future e-commerce market growth will primarily be driven by consumer purchasing behavior. Therefore, China's e-commerce development should focus more on strategies emphasizing product quality and service quality. Additionally, while the e-commerce market still holds significant potential for development in the coming years, its growth rate may gradually decline.

4.1.3 Analysis of the current situation of e-commerce development in each province

As shown in Table 1, China's 31 provinces demonstrated significant growth in e-commerce development from 2013 to 2021. This indicates that e-commerce has become an increasingly vital sector in the Chinese economy. Beijing, Guangdong, Zhejiang, Jiangsu, and Shanghai achieved total scores of 5.6870,3.6376,3.1904,2.7678, and 2.2702 respectively over nine years, demonstrating notably higher development levels than other provinces—a finding consistent with common perceptions. Notably, after Beijing, Guangdong, Zhejiang, Jiangsu, and Shanghai, the scores of other provinces remained relatively close, mostly ranging between 1 and 3. This suggests potential for further growth in e-commerce development beyond major cities. Provinces in central and eastern China such as Jiangsu, Zhejiang, Guangdong, and Anhui scored higher than western regions like Xizang and Xinjiang. These regional disparities highlight both the development gaps in e-commerce and the challenges faced by less developed areas in advancing e-commerce.

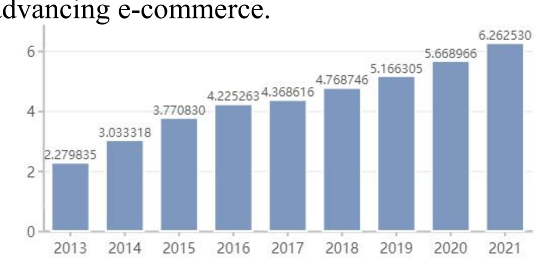

Figure 1. Development Level of E-Commerce in China

As shown in Table 2, developed regions such as Beijing, Shanghai, Guangdong, and Zhejiang demonstrate advanced e-commerce development with well-established ecosystems and industry leaders including Alibaba, JD.com, and Suning. These areas boast high population density and strong consumer purchasing power, creating a solid market foundation for e-commerce growth. Jiangsu, Shandong, and Fujian also show notable progress, with Fujian ranking third nationally in e-commerce transaction volume. Their competitive edge stems from robust manufacturing and export industries, providing abundant product resources [25]. While central and western regions have slower e-commerce development, they've been actively advancing in recent years. Sichuan, Hunan, and Hubei stand out with growing e-commerce enterprises and expanding transaction volumes Xizang. Regions like Qinghai lag behind due to remote locations, poor transportation, sparse populations, and limited market size [26]. However, with internet penetration and policy support, these areas are now accelerating their e-commerce development. Overall, China's provinces exhibit regional disparities in e-commerce advancement, but the sector continues to grow steadily. Supported by internet adoption and policy incentives, e-commerce development remains promising nationwide.

4.1.4 Analysis of regional E-commerce development level in China

Based on the Administrative Division Codes of the People's Republic of China, this study categorizes the country's 31 provinces into seven regions. Each region forms a separate group to examine the current status of regional e-commerce development and lay the groundwork for subsequent heterogeneity analysis. The sample is divided into North China, Northeast China, East China, Central China, South China, Southwest China, and Northwest China. Specifically: East China includes Shandong, Jiangsu, Anhui, Zhejiang, Fujian, and Shanghai; South China comprises Guangdong, Guangxi, and Hainan; Central China covers Hubei, Hunan, Henan, and Jiangxi; North China encompasses Beijing, Tianjin, Hebei, Shanxi, and Inner Mongolia; Northwest China consists of Ningxia, Xinjiang, Qinghai, Shaanxi, and Gansu; Southwest China includes Sichuan, Yunnan, Guizhou, Xizang, and Chongqing; Northeast China comprises Liaoning, Jilin, and Heilongjiang. By aggregating the e-commerce development index scores of each region and calculating the average value (divided by the number of provinces), we derive regional e-commerce development levels. The resulting values and their evolving trends are illustrated in Figure 2.

4.2 Dependent Variable

4.2.1 Construction of technology innovation level evaluation system

The dependent variable in this study is the regional level of technological innovation. While academic circles commonly use patent grants, patent applications, or the proportion of invention patents among total patents as indicators of technological innovation, some also employ the ratio of invention patents and utility model patents to the national average as measurement criteria—these approaches being essentially similar. To ensure research validity and minimize data errors, this paper adopts three key metrics: patent grants (PG), patent applications (PA), the ratio of patent acceptance volume to population (GOP), and the proportion of invention patents in total patent acquisitions (IOT). Following the methodology used in constructing e-commerce development evaluation systems, we developed a regional technological innovation assessment framework using identical analytical approaches. All variables underwent i-processors for statistical analysis, with entropy weighting applied for evaluation. The results are presented in Table 6.

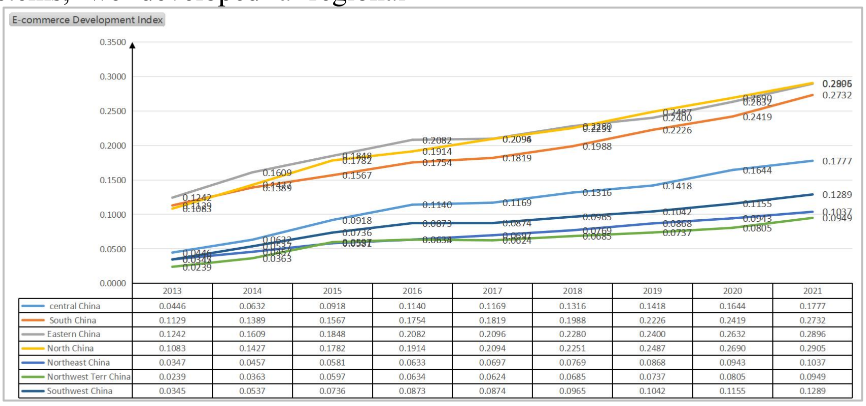

Figure 2. Development Level of Regional E-Commerce in China

Table 6. Weight of Technological Innovation Level Index

K: 0.177582	Patent authorization volume	Number of patent applications	The ratio of the number of patents accepted to the population	The proportion of invention patents in the total number of patents obtained
ej	0.889	0.878	0.902	0.978
gij	0.111	0.122	0.098	0.022
W	0.316	0.345	0.277	0.062

As shown in Table 6, the weighted indicators for patent authorization volume, patent application volume, ratio of patent acceptance volume to population, and proportion of invention patents among all patents are 0.316, 0.345, 0.277, and 0.062 respectively. By applying MMX processing to these indicators, multiplying them with corresponding weights, and then summing up the results, we derive the regional technological innovation level index. A higher value indicates greater technological innovation capability in the region. The calculation formula is as follows (3):

"Y=0.316*PG+0.345*PA*+0.277*GOP+0.062 *IOT" (3)

According to the above formula, the technological innovation level of China (as shown in Figure 3) and regional technological innovation level (as shown in Table 7) are obtained.

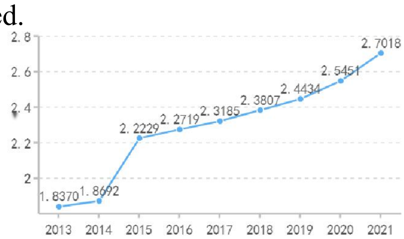

Figure 3. National Technological Innovation Level

4.2.2 Analysis of the current situation of E-commerce development in China

As shown in Figure 3, China's technological innovation level index has demonstrated a sustained upward trend over the past few years. Starting from 1.8370 in 2013 and reaching 2.7018 in 2021, this index maintained an annual growth rate of approximately 3.76%, indicating China's rapid advancement in technological innovation. Notably, the exponential growth between 2014-2015 stood out significantly compared to other periods, marking a breakthrough year for China's technological innovation. This milestone likely resulted from intensified policy support and investment in technological innovation during that period. From 2016 to 2021, the index continued to grow at an average annual rate of 3.78%, demonstrating substantial returns on investment and confirming China's commitment to sustaining high-speed technological innovation in the future. Furthermore, since 2018, the index's growth rate has accelerated, likely driven by enhanced policy initiatives—particularly investments in key areas like artificial intelligence, advanced materials, and renewable energy—further accelerating the pace of technological advancement.

Table 7. Regional Technological Innovation Level in China

	North China	Northeast China	Eastern China	Southwest	Northwest Terr	Central China	South China	mean
2013	0.0454	0.0414	0.1263	0.0363	0.0328	0.0332	0.0831	0.0569
2014	0.0494	0.0412	0.1206	0.0392	0.0339	0.0363	0.0882	0.0584
2015	0.0570	0.0441	0.1487	0.0478	0.0340	0.0441	0.1093	0.0693
2016	0.0607	0.0438	0.1492	0.0456	0.0345	0.0469	0.1179	0.0712
2017	0.0640	0.0435	0.1491	0.0435	0.0351	0.0498	0.1271	0.0732
2018	0.0677	0.0433	0.1503	0.0419	0.0357	0.0527	0.1371	0.0755
2019	0.0713	0.0431	0.1498	0.0417	0.0382	0.0555	0.1457	0.0779
2020	0.0754	0.0429	0.1523	0.0431	0.0411	0.0585	0.1569	0.0815
2021	0.0811	0.0430	0.1599	0.0451	0.0451	0.0621	0.1694	0.0865
mean	0.0636	0.0429	0.1451	0.0427	0.0367	0.0488	0.1261	

4.2.3 Analysis of regional technological innovation level in China

According to the grouping in Section 4.1.1, the technological innovation level index of corresponding provinces within each group was added and divided by the number of provinces in that group, yielding the regional technological innovation level. The results show China's regional technological levels as presented in Table 7. Overall, all regions demonstrated a yearly upward trend in technological innovation levels, indicating significant progress in China's technological advancement. Notably, the East China region has maintained its leading position in technological innovation. Comparative analysis reveals that from 2013 to 2016, South China, East China, and Central China generally outperformed other regions. From 2017 to 2021, North China and Northeast China saw gradual improvements in technological innovation levels, with Northeast China showing particularly rapid growth, though still lagging behind other regions. Growth rates varied significantly: East China recorded the fastest growth rate at an average annual

increase of 5.71% between 2013 and 2021, while Northwest China had the slowest growth rate at merely 2.00% per year, accompanied by considerable fluctuations. Regional disparities remain pronounced, with Northeast and North China demonstrating notably lower innovation levels compared to others. Enhanced investment and policy support are crucial to boost technological innovation in these areas. On average, East China's technological innovation level is the highest nationwide, twice the national average, whereas Northwest China's remains the lowest, approximately 60% of the national average. This highlights the significant disparities in technological innovation capabilities across regions, particularly in Northwest China, where substantial investment in R&D is urgently needed to enhance innovation capacity. While China has achieved remarkable progress in technological innovation with varying degrees of improvement across regions, the era of rapid development demands that innovation remain paramount. Therefore, it is crucial to strengthen policy support and investment in technological advancement, elevate innovation levels nationwide, and continuously amplify technology's role in driving socioeconomic progress. Concurrently, efforts should focus on building robust innovation ecosystems to boost efficiency, improve output quality, and propel China's modernization toward becoming a science-driven nation and ultimately an innovative powerhouse.

4.3 Research Model

In order to study the impact of e-commerce development on technological innovation in different regions, this paper constructs the following research model:

$$Y_{pt} = \beta_0 + \beta_1 X_{pt} + \beta_2 Control_{pt} + \alpha_p + \alpha_t + \varepsilon_{pt} \quad (4)$$

In the model, p denotes the province, t represents the year, Y stands for the technological innovation index, X indicates the e-commerce development level α_p α_p , and Control α_t denotes α_t the control variable. Additionally ε_{pt} , the model ε_{pt} incorporates provincial fixed effects () and annual fixed effects (), which help control for unobservable provincial and temporal variables. The random disturbance term is included to account for inherent variations.

4.4 Control Variables

Referring to the existing literature on the development of e-commerce and technological innovation, this paper selects the following variables as control variables 1) economic development quality (CGDP): According to the research of Li & Xie [27], the level of economic development may have an impact on technological innovation, so this paper introduces the level of economic development as a control variable. (1) Per capita GDP is used as the measurement indicator; (2) Transportation Infrastructure (RRA): measured by road mileage/area (RRA1) and railway mileage/area (RRA2); (3) Openness Level (OUL): referencing studies by Xu&Lu [28], and Wang& Wang [29], foreign investment has an impact on regional technological innovation, and the number of foreign-invested enterprises is also a contributing factor. Therefore, this paper adopts foreign investment/GDP ratio (RFIA) and the number of foreign-invested enterprises (NFE) to measure openness; (4) Financial Development Level (RFIP): based on Sun & Zhu [30]'s research, financial development may influence technological innovation. This paper measures it through the proportion of financial industry employees; (5) Education Level (RNHEI): according to Xie [31]'s study, education may affect corporate technological innovation. This paper measures regional education level using the ratio of regular university students to permanent population; (6) R&D Investment (RD): measured by R&D expenditure. Following Chi's research [32], innovation investment positively impacts technological innovation levels. This paper uses R&D expenditure to gauge R&D investment.

4.5 Sample Selection and Data Sources

The data for evaluating e-commerce development and technological innovation in this study were sourced from the Guotai An Database and the National Bureau of Statistics. We selected data from all 31 provincial-level administrative regions in Chinese Mainland (due to data availability constraints) spanning from 2013 (the inaugural year of e-commerce) to 2021. The data underwent the following processing steps: converting the format into panel data, supplementing missing values using linear interpolation/extrapolation methods, and replacing negative values with zero. The variable explanations and descriptive statistics are presented in Table 8.

5. Empirical Process, Empirical Results and Analysis

5.1 Empirical Process

This study employs methods outlined in sections 3.2.1 and 3.2.3 to determine e-commerce development (X) and technological innovation (Y) levels across provincial administrative regions. The dataset was transformed into panel data, and regression analyses were conducted using uncontrolled variables, controlled variables, time-fixed effects models, and time-individual fixed effects models respectively. These analyses ultimately reveal the impact of e-commerce development on technological innovation.

Table 8. Descriptive Statistics

Variable code and unit	Variable name	sample number	mean	variance	least value	crest value	data sources
Y		279	0.0738	0.0669	0.000311	0.410	It was calculated
X		279	0.142	0.135	0.0121	0.871	It was calculated
IOW (100 million)	Investment in information transmission, computer services and software industries and total fixed asset investment	279	222.2	184.0	0	1,075	Guotai data
NOD (10,000)	Number of domain names registered under Cn	279	107.6	144.9	0.499	882.5	Guotai data
NOW (individual)	Number of websites	279	816,692	1.803e+06	9.619	1.232e+07	Guotai data
EPR (thousands of people)	Number of people in software and information technology services	279	13.11	16.81	0.442	101.2	Guotai data
POS (percentage)	The share of e-commerce sales in GDP	279	0.131	0.128	0.00599	0.776	It was calculated
ASQ	E-commerce sales to population ratio	279	1.087	1.946	0	14.27	It was calculated

POP (percentage)	The proportion of e-commerce purchases in GDP	279	0.0745	0.0783	0.00212	0.446	It was calculated
APQ	E-commerce purchase volume to population ratio	279	0.623	1.164	0	7.746	It was calculated
NOE (individual)	Number of enterprises with e-commerce transactions	279	3,095	3,502	18	19,257	Guotai data
POA (percentage)	The proportion of e-commerce transaction enterprise activities	279	8.789	3.773	1.500	23.50	Guotai data
EPS (first)	Average wages in information transmission, software and information technology services	279	105,987	45,525	39,962	303,573	Guotai data
IPR (percentage)	Internet penetration rate	279	0.556	0.114	0.325	0.872	It was calculated
PG (individual)	Patent authorization volume	279	50,791	65,053	0	348,312	Guotai data
PA (individual)	Number of patent applications	279	120,097	173,226	169	1.155e+06	Guotai data
GOP (per 100 million)	The ratio of the number of patents accepted to the population	279	26.79	32.46	0	162.1	Guotai data + calculation
IOT (percentage)	The proportion of invention patents in the total number of patents obtained	279	0.334	0.154	0	0.859	Guotai data
Road (km)	highway mileage	279	15.49	8.260	1.260	39.89	State Statistical Bureau
FIP (thousands of people)	Financial industry employees	279	22.47	15.68	0.900	95.30	State Statistical Bureau
NHEI (thousands of people)	Number of students in regular higher education institutions	279	92.24	57.97	3.350	268.6	State Statistical Bureau
Rail (kilometre)	Rail mileage	279	27,139	22,988	828.2	124,720	State Statistical Bureau
NFE (one-panelled door)	Number of foreign-invested enterprises	279	17,748	29,733	221	185,553	State Statistical Bureau
FIA (One million dollars)	Foreign investment	279	257,981	473,695	1,311	4.527e+06	State Statistical Bureau
Population (10,000)	population	279	4,495	2,931	317	12,684	State Statistical Bureau
GDP (100 million)	gross domestic product	279	27,666	22,903	815.7	124,370	State Statistical Bureau
CGDP (first)	per capita gross domestic product	279	61,526	29,267	23,151	183,980	State Statistical Bureau
RD (Wan Yuan)	R&D put into	279	3.952e+06	5.208e+06	2,602	2.902e+07	State Statistical Bureau
RRA1	Highway mileage/area	279	0.947	0.533	0.0575	2.245	It was calculated
RRA2	Rail mileage/area	279	4,152	9,675	6.742	68,854	It was calculated
RFIA	Foreign investment /GDP	279	10.98	51.18	0.764	699.2	It was calculated
RFIP	Financial development level	279	0.00568	0.00426	0.00212	0.0295	It was calculated
RNHEI	educational level	279	0.0207	0.00567	0.00888	0.0425	It was calculated
RRA	Transport infrastructure level	279	0.467	0.339	0	1.918	It was calculated
OUL	The level of opening to the outside world	279	0.109	0.179	0.00115	1.032	It was calculated

5.2 Empirical Process

This study employs methods outlined in sections 3.2.1 and 3.2.3 to determine e-commerce development (X) and technological innovation (Y) levels across provincial administrative regions. The dataset was transformed into panel data, and regression analyses were conducted using uncontrolled variables, controlled variables, time-fixed effects models, and time-individual fixed effects models respectively. These analyses ultimately reveal the impact of e-commerce development on technological innovation.

5.3 Empirical Analysis

The results of applying the fixed effects model to analyze the impact of e-commerce development on technological innovation are shown in Table 9. Column (1) presents regression results without control variables, revealing that the coefficient of e-commerce development's impact on regional technological innovation is 0.8276 at the 1% significance level, indicating a significant positive effect. Column (2) incorporates potential control variables affecting technological innovation, showing a coefficient of 0.3136 with statistical significance, confirming its positive impact. Column (3) combines these control variables with time and region fixed effects, yielding a coefficient of 0.5581 at the 1% level, further validating the positive correlation. Column (4) integrates all three effects, demonstrating a coefficient of 0.5737 at the 1% significance level, maintaining the positive influence. Overall, while introducing control variables reduces the coefficient of e-commerce's impact on technological innovation, the positive effect persists. The inclusion of time and region fixed effects enhances explanatory power but does not alter the conclusion of its positive influence. Therefore, it can be concluded that the development of e-commerce has a positive role in promoting technological innovation. Then, the government and enterprises should pay attention to the impact of e-commerce development on technological innovation, actively guide and support technological innovation, so as to promote economic development and drive technological progress.

Regarding control variables, in Column (2), the coefficient of transportation infrastructure level is-0.2176 and statistically significant at the 1% level, indicating that higher transportation infrastructure levels are detrimental to technological innovation, while improvements in economic development quality may also negatively impact technological advancement. Conversely, the coefficients for openness level and R&D investment are 0.1499 and 0.1664 respectively, both statistically significant at the 1% level, suggesting that greater openness and increased R&D investment are beneficial for technological innovation. The effects of economic development level, financial development level, and education level were less significant. After controlling for time effects, the impacts of transportation infrastructure level, openness level, and R&D investment remained unchanged, but the positive effect of openness level on technological innovation became statistically significant at the 10% level. While the conclusion about higher transportation levels correlating with lower technological innovation differs from existing literature, other findings are consistent. Regarding the observation that higher transportation levels correlate with lower technological innovation, this paper proposes two explanations: First, in resource allocation, some regions may prioritize investments in transportation infrastructure and transport systems over technological innovation. Second, stakeholders in certain areas might prefer maintaining existing transportation systems rather than supporting technological innovation, as they have already invested substantial capital and resources into current systems, whereas technological innovation requires greater investment and risk. Additionally, in cultural and educational contexts, some regions may emphasize tradition and experience over innovation and technology. This may affect people's attitudes and willingness to adopt technological innovation.

Table 9. Fixed Effect Model Regression Results

	(1)	(2)	(3)	(4)
	Y	Y	Y	Y
X	0.8276***	0.3136***	0.7222***	0.6869***
	(0.0000)	(0.0014)	(0.0000)	(0.0000)
The level of economic development		-0.0559	-0.0363	-0.0388
		(0.2368)	(0.4282)	(0.3976)
Transportation level		-0.2176***	-0.2321***	-0.2336***
		(0.0001)	(0.0000)	(0.0000)
The level of opening to the outside world		0.1499***	0.0939*	0.0644
		(0.0054)	(0.0824)	(0.2566)
Financial development level		-0.0274	0.0136	0.0148
		(0.5501)	(0.7670)	(0.7625)
educational level		-0.0169	0.0198	0.0258
		(0.7096)	(0.6566)	(0.5660)

research input		0.1664***	0.1442***	0.1251**
		(0.0017)	(0.0062)	(0.0237)
_cons	-1.0917***	-1.8702***	-0.6304*	-1.0755***
	(0.0000)	(0.0000)	(0.0608)	(0.0061)
time effect	Not controlled	Not controlled	control	control
Individual effects	Not controlled	Not controlled	Not controlled	control
N	279	279	279	279
r2_a	0.4218			

5.4 Heterogeneity Analysis

As an extension of linear regression, grouped regression stands as one of the most widely used methods for analyzing heterogeneity. This approach involves grouping samples based on specific characteristics and conducting regression analyses within each group. For instance, data might be divided into subgroups according to gender, age, education level, or other factors, followed by separate regression analyses. The primary advantage of grouped regression lies in its ability to effectively explore heterogeneous differences among subgroups, thereby providing a more accurate representation of overall data characteristics. Additionally, it helps reduce model complexity and enhance interpretability. However, this method requires prior sample grouping, and improper or inaccurate categorization may compromise result accuracy. Moreover, grouped regression demands multiple regression analyses, which can be computationally intensive and resource-intensive. The operational steps are as follows: First, determine grouping variables and methods based on research objectives and data characteristics; then divide samples into groups with similar features; conduct regression analysis within each group to obtain individual models; compare these models to identify subgroup-specific heterogeneity; and finally interpret the results to describe the overall dataset. This study employs grouped regression for regional heterogeneity testing. Based on the grouping criteria outlined in Section 4.1.4, this study conducted regression analyses across seven regions: North China, Northeast China, East China, Central China, South China, Southwest China, and Northwest China. The model controlled for key variables including per capita GDP, transportation infrastructure, openness to foreign investment, financial development, education level, and R&D investment, while also accounting for time effects. The final regression results are presented in Table 10.

Table 10. Regional Heterogeneity

	North China	Northeast China	Eastern China	central China	South China	Southwest China	Northwest Terr China
	Y	Y	Y	Y	Y	Y	Y
X	0.1347**	0.6122**	1.0279***	-0.0556	0.0017	0.5403	2.4713***
	(0.0330)	(0.0201)	(0.0000)	(0.7312)	(0.9983)	(0.4353)	(0.0002)
_cons	-1.8073***	-3.3421***	-0.7406**	-4.4515***	0.0419	0.1317	3.2755*
	(0.0000)	(0.0000)	(0.0268)	(0.0000)	(0.9697)	(0.9451)	(0.0755)
controlled variable	control	control	control	control	control	control	control
time effect	control	control	control	control	control	control	control
N	45	27	63	27	27	45	45

5.5 Regression Results

The results in the table demonstrate significant regional disparities in the impact of e-commerce development on technological innovation. The coefficients for North China, Northeast China, East China, and Northwest China are 0.1347,0.6122,1.0279, and 2.4713 respectively, all statistically significant at the 5% level with North China and Northeast China achieving significance at the 1% level. This indicates that e-commerce development exerts a highly significant positive influence on technological innovation across these regions, with Northwest China showing the strongest effect (coefficient 2.4713), followed by East China (1.0279) and Northeast China (0.6122). In contrast, North China demonstrates the weakest impact (0.1347). Notably, e-commerce development shows no significant effect on technological innovation in Central China, South China, and Southwest China.

5.6 Robustness Test

This paper employs five robustness testing methods to evaluate statistical approaches for data validation. These methods assess data stability and reliability, determining its suitability for further analysis and decision-making. The process simultaneously detects outliers and anomalous values within datasets, excluding them from statistical analyses to ensure quality assurance. This approach enhances decision accuracy and credibility while preventing erroneous conclusions drawn from unreliable data, thereby saving time and resources while avoiding unnecessary losses. The robustness test results are presented in Table 11.

(1) Lagged one-period explanatory variable. Conducting robustness tests on the year of X lagged by one period, the results shown in column 1 indicate a coefficient of 0.6254 with statistical significance at the 1% level, demonstrating that e-commerce development still exerts a significant positive influence on technological innovation under this lagged test. (2) Capping X values by 5%. After capping X values by 5% to obtain Xs for robustness testing, the results in column 2 show a coefficient of 0.6361 with significance at the 1% level, confirming the positive impact of e-commerce development on technological innovation under this capped test. (3) Capping Y values by 5%. The capped Y values (Ys) in column 3 reveal a coefficient of 0.4227 with statistical significance at the 1% level, indicating sustained positive effects of e-commerce development on technological innovation under this capped test. (4) Adjusting explanatory variable values. Given that the indicator weight of NOW reaches its maximum value of 0.462, removing this indicator yields XNow for robustness testing, with a coefficient of 6.3669 at the 1% level, demonstrating the significant positive influence of e-commerce development on technological innovation under adjusted variable testing. (5) Replacing explanatory variables. Since e-commerce procurement volume can also represent the development level of e-commerce to some extent, we use e-commerce procurement volume as a substitute for X in robustness tests. The results shown in column 5 show that the coefficient is 0.1338 and statistically significant at the 1% level, indicating that e-commerce development still has a significant positive impact on technological innovation when replacing similar explanatory variables.

According to the results of the above robustness test, the coefficients of the core explanatory variable e-commerce development level are all significantly positive and significant at least at the 1% significance level, which to some extent proves the robustness of the regression results in this paper.

Table 11. Robustness Test

		1	2	3	4	5
	Y	Y	Y	Ys	Y	Y
X	0.4700***			0.4227***		
	(0.0000)			(0.0000)		
L.X		0.6254***				
		(0.0006)				
Xs			0.6361***			
			(0.0000)			
X_NOW					6.3669***	
					(0.0000)	
E-commerce purchase volume						0.1338***
						(0.0047)
_cons	-5.1404**	-5.5506*	-16.2553***	-9.2130***	-16.4074***	-17.4699***
	(0.0416)	(0.0727)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
controlled variable	control	control	control	control	control	control
time effect	control	control	control	control	control	control
N	279	248	279	279	279	279
r2_a	0.6795	0.7035				

6. Conclusions and Policy Recommendations

6.1 Research Conclusions

This study utilizes provincial panel data spanning 2013-2021, the first year of China's e-commerce development, to comprehensively evaluate the growth and technological innovation capabilities of e-commerce across all Chinese provinces. Through multidimensional analysis, it investigates how regional e-commerce development impacts technological advancement in China. The research ultimately reveals the following key findings:

(1) This study develops an e-commerce development measurement framework based on Analytic Hierarchy Process (AHP), comprising four primary indicators: transaction volume, digitalization level, human capital capacity, and ecosystem environment. The secondary indicators include: e-commerce sales as a percentage of GDP; the ratio of investments in information transmission, computer services, and software to total fixed asset investment; domain registrations under China's CN system (in ten thousand units); website count (in ten thousand units); internet penetration rate; e-commerce employee compensation levels; number of e-commerce enterprises; and proportion of business activities conducted online. Through entropy weighting methodology, we calculated weights for each indicator, effectively reducing subjective judgment inherent in expert evaluations. Analysis reveals that China's provincial e-commerce development indices have shown steady growth with linear progression, demonstrating continuous advancement across all regions.

(2) Empirical analysis demonstrates that e-commerce development exerts a remarkably positive influence on technological innovation. The higher the level of e-commerce development, the more it facilitates improvements in both innovation output and efficiency. This conclusion aligns with practical realities: The rapid advancement of e-commerce not only creates broader development opportunities and richer data resources for technological innovation, but also provides more application scenarios that accelerate its progress.

(3) The impact of e-commerce development on technological innovation shows regional heterogeneity. The most significant positive effects are observed in the Northwest region, followed by East China and Northeast China, with minimal influence on North China. The effects on Central China, South China, and Southwest China are not statistically significant. Potential reasons include inadequate government oversight of local e-commerce enterprises, ineffective regulation of unhealthy competition practices, and insufficient protection of corporate interests in technological innovation. This conclusion demonstrates that factors such as regional economic development levels, industrial structures, and policy environments vary across regions, necessitating tailored policies and measures to address these differences.

In conclusion, this study has identified a series of valuable insights through analyzing China's e-commerce development and technological innovation. These findings provide crucial guidance for formulating more scientific policies on e-commerce and technological advancement, thereby driving the growth and innovation of China's e-commerce sector. Furthermore, the research methodology and analytical framework established in this paper offer valuable references for future studies in related fields.

6.2 Policy Recommendations

Based on the above research conclusions, this paper puts forward the following policy suggestions:

(1) Given the significant catalytic effect of e-commerce development on technological innovation, governments should intensify efforts in cultivating e-commerce professionals by establishing a comprehensive talent development system. This will provide the industry with more high-caliber talents to drive technological advancement while strengthening the integration between e-commerce and scientific innovation. Governments should encourage collaboration between e-commerce enterprises and tech innovation institutions to jointly conduct R&D projects, thereby enhancing the sector's technical capabilities and competitiveness. Intellectual property protection must be reinforced through the establishment of robust safeguard mechanisms, creating a stable and favorable environment for innovation. Policy support and guidance should be enhanced to incentivize enterprises to strengthen partnerships with government agencies, fostering coordinated progress in both industry growth and technological breakthroughs. International cooperation should also be prioritized through active engagement with foreign counterparts in e-commerce and tech innovation sectors, collectively advancing global competitiveness. In conclusion, the role of e-commerce in driving technological innovation cannot be overstated. The nation

should implement preferential policies, prioritize talent development, promote cross-sector collaboration, strengthen IP protection measures, increase governmental support, and actively engage in international cooperation to collectively propel the evolution and technological advancement of the e-commerce industry.

(2) Strengthen the development of e-commerce in northwest China and further enhance the level of technological innovation;

Research findings indicate that e-commerce development has exerted the most significant impact on technological innovation in Northwest China. Therefore, the government should enhance support and guidance for e-commerce in this region to further elevate technological innovation capabilities. Specific recommendations include: 1) Increasing financial investment to provide enterprises with more funding support for technological advancement; 2) Strengthening talent cultivation by enhancing technical proficiency and fostering innovative thinking among e-commerce professionals in the northwest; 3) Promoting industrial collaboration through policy incentives, encouraging enterprises to strengthen partnerships with upstream and downstream partners to build complete industrial chains and boost overall competitiveness; 4) Implementing preferential policies such as tax breaks and fiscal subsidies to offer greater support to e-commerce businesses in the northwest.

(3) Give full play to the promoting role of e-commerce in various industries through various ways.

To address the positive impact of e-commerce development on technological innovation in North China, Northeast China, East China, and Northwest China, it is recommended that governments strengthen collaboration with e-commerce enterprises to encourage technological innovation and enhance technical capabilities. Simultaneously, authorities should increase support for e-commerce businesses to boost market competitiveness and promote industrial transformation. Policy support should be intensified. The state should introduce more favorable policies to provide greater assistance to regional e-commerce enterprises, such as tax incentives and fiscal subsidies. Technical innovation training programs should be strengthened to improve both corporate and professional technical proficiency, thereby enhancing innovation capabilities. Industrial chain development needs to be prioritized. Governments should enhance the construction of regional e-commerce industrial chains, guiding enterprises to strengthen cooperation with upstream and downstream partners to form complete industrial chains and boost overall competitiveness. Government guidance should be reinforced. The nation should intensify its role in steering e-commerce development in Northeast China, encouraging enterprises to collaborate closely with government agencies to jointly advance e-commerce growth and elevate technological innovation standards.

(4) Strengthen inter-regional cooperation to promote the development of e-commerce and the upgrading of technological innovation

Through analyzing the heterogeneous impacts of e-commerce development on technological innovation, governments should enhance cross-regional collaboration. This includes strengthening cooperation between different regions to promote resource sharing, technical exchanges, and industrial complementarity, thereby boosting overall competitiveness. Establishing mutually beneficial cooperation mechanisms is crucial. The state should create reciprocal frameworks that encourage enterprises to collaborate closely, jointly advancing e-commerce development and elevating technological innovation capabilities. Enhanced information sharing will facilitate inter-regional communication and cooperation, further improving technological innovation levels. Policy coordination must be strengthened through unified guidelines and standards to promote coordinated regional development. In conclusion, e-commerce development significantly influences technological innovation. Governments should tailor support measures according to regional conditions, guiding technological advancement while fostering inter-regional cooperation to achieve mutual benefits and win-win outcomes.

References

[1] Zhao Xiaojun, Liu Xiaoying, Sang Yihan, et al. The heterogeneous impact of e-commerce development on industrial structure upgrading —— An empirical analysis based on China's interprovincial panel data. Industrial Technology & Economics, 2021, 40(07):134-140.

[2] Wu Guanrong, Chen Yueqin. The Impact of E-commerce Development on the Urban-Rural Income Gap —— A Study Based on China's Interprovincial Panel Data. Logistics Engineering & Management, 2022, 44(01):88-90+43.
[3] Nie Linhai. Characteristics and Trends of E-commerce Development in China. Circulation Economy of China, 2014, 28(06):97-101.
[4] Xu Deyun. A theoretical explanation and verification of the determination and measurement of industrial structure upgrading pattern. Journal of Finance, 2008, 299(01):46-49.
[5] Yang Jianzheng, Zhou Tao, Li Qingzi. An empirical study on the role of e-commerce in economic growth. World Economic Research, 2011, 212(10):40-43+88.
[6] Lin Kongtuan, Yu Jing. An empirical analysis on the impact of e-commerce on provincial economic growth. Journal of Fujian Normal University (Philosophy and Social Sciences Edition), 2017, 204(03):23-31+168.
[7] Rana Deljavan Anvari, Davoud Norouzi. The Impact of E-commerce and R & D on Economic Development in Some Selected Countries. Procedia-Social and Behavioral Sciences, 2016, 229:354-362.
[8] Zeng Shihong, Gao Yalin. Mechanism, Path and Countermeasures of Internet Technology Innovation Driving Service Industry Transformation and Upgrading. Journal of Hunan University of Science and Technology (Social Sciences Edition), 2016, 19(05):123-127.
[9] Dong Yu, Yang Jingjing. The Impact of Logistics Development on the Complexity of Export Technology —— A Study Based on China's Interprovincial Panel Data. International Business. Journal of University of International Business and Economics, 2016, 169(02):29-38.
[10] Li Jing. Spatial Coordinated Development of Digital Finance and Urban Commercial Vitality in China —— On the Spatial Spillover Effects of Industrial Integration. Journal of Commercial Economics, 2021, 828(17):178-181.
[11] Hao Feilong, Guan Haoming, Wang Shijun. Spatial distribution characteristics and influencing factors of urban e-commerce development in China. Economic Geography, 2016, 36(02):1-10.
[12] Yao Huili. Measurement and Analysis of Regional E-commerce Development Level. Statistics and Decision, 2019, 35(14):105-108.
[13] Jia Yajun. Measurement of the Integrated Development Level of Urban and Rural Commercial Circulation and Analysis of Its Influencing Factors. Journal of Commercial Economy, 2023, 866(07):31-34.
[14] Zhang Hong, Wang Haoran, Li Zhe. Measuring the High-Quality Development Level of China's Digital Agriculture under the Background of Rural Revitalization —— An Analysis Based on Data from 31 Provinces and Cities in China from 2015 to 2019. Journal of Shaanxi Normal University (Philosophy and Social Sciences Edition), 2021, 50(03):141-154.
[15] Jiang Xuemei, Zhou Enbo. Fiscal Decentralization, Environmental Regulation and Technological Innovation. Management Modernization, 2022, 42(05):1-9.
[16] Lei Xiaoli. Digital Finance, Technological Innovation and Green Total Factor Productivity of Circulation Industry. Business Economics Research, 2022, 857(22):15-18.
[17] Su Yongwei, Liu Zexin. Research on the Threshold Effects of Logistics Efficiency, Technological Innovation and Modern Service Industry Development —— An Analysis Based on Provincial Panel Data. Macroeconomic Research, 2022, 284(07):149-162.
[18] Chen Lin. An Empirical Study on Digital Finance and Technological Innovation. Investment and Entrepreneurship, 2022, 33(19):1-3.
[19] Lü Yu. E-commerce Development, Economic Policy Uncertainty and Innovation of Commercial Circulation Enterprises. Business Economics Research, 2022, 846(11):83-86.
[20] Tian Shuo, Sun Ailin. The Impact of Digital Economy on Innovation of Chinese Manufacturing Enterprises. Economic Issues, 2023, 526(06):41-49.
[21] Wu Qian, Yao Leye. Digital Economy, Innovation-driven Development and Regional Economic Growth. Soft Science: 1-12 [2023-05-22].
[22] Zou Wenfeng, Wang Qing, Huang Huiliang. Research on Innovation and

Development of Modern Enterprise Logistics Management in E-commerce Environment. Business Economics, 2023, 562(06):71-73+186, 40(21):143-153.
[23] Zhou Yangwenqian. Study on the Internal Evolution Mechanism of Two Types of Innovation and Its Impact Mechanism on Economic Growth. Shanghai University of Finance and Economics, 2021.
[24] Zhang Jincan, Deng Yunjie, Zhang Juntao. Cross-border E-commerce, Business Environment and High-quality Development of Foreign Trade. Price Theory and Practice: 1-4 [2023-05-18].
[25] Wang Xuan, Wang Haining, Chen Zhaoxu. Study on the Development Level Difference of E-commerce in China Based on Spatial Econometric Model. Journal of Commercial Economics, 2020, 807(20):87-89.
[26] Zhang Peipei. Research on regional differences and influencing factors of technological innovation efficiency in China's high-tech industry. Jiangxi University of Finance and Economics, 2017.
[27] Li Chang'e, Xie Yongzhen. The Impact of Regional Economic Development Level and Female Directors on Corporate Technology Innovation Strategy. Socioeconomic System Comparison, 2016, 186(04):120-131.
[28] Xu Helian, Lu Xuehuan. The Impact of Foreign Direct Investment on Technological Innovation Capability —— An Empirical Study Based on China's Industrial Data. Finance Theory and Practice, 2008, 155(05):88-93.
[29] Wang Yanli, Wang Zhongying. Analysis of the Impact Pathways of Foreign Direct Investment on Technological Innovation —— Based on Threshold Characteristics and Spatial Spillover Effects. Management Modernization, 2018, 38(03):58-61.
[30] Sun Wuqin, Zhu Shunlin. Research on the efficiency of financial development in promoting technological innovation. —— Analysis based on Malmuquist index. Statistical Research, 2008, 197(03):46-50.
[31] Xie Fenghua, Yao Xianguo, Gu Jiajun. An empirical study on the relationship between high-level management team heterogeneity and enterprise technological innovation performance. Research Management, 2008, 159(06):65-73.
[32] Chi Renyong. Research on enterprise technological innovation efficiency and its influencing factors. Quantitative & Technical & Economic Research, 2003(06):105-108.