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The impact of internet on innovation of manufacturing export enterprises: Internal mechanism and micro evidence

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ABSTRACT

Based on the matching data in the China Customs, Chinese industrial enterprises, and patent databases, this study uses the propensity score matching method (PSM) and the double difference model (DID) to study the impact of Internet use on enterprise innovation. The results show that Internet use can significantly promote the innovation level of China's manufacturing export enterprises, with obvious heterogeneity among regions. Compared with the central and western regions, the role of the Internet in promoting manufacturing export enterprises' innovation in the eastern region is more significant. Compared with the non-coastal regions, manufacturing export enterprises in the coastal regions benefit more. The promotion effect of the Internet on manufacturing export enterprises' innovation has a scale threshold and varies by ownership type: it is more significant on large and medium-sized enterprises, while state-owned enterprises have a higher innovation level than private enterprises. Mechanism analysis shows that Internet applications can, indeed, promote manufacturing export enterprises' innovation by reducing export costs and management innovation costs.

The digital economy is becoming the driving force of development leading the era, and the use of the Internet has an important impact on enterprise digitalization and enterprise innovation. Based on the data of Chinese manufacturing enterprises, this study uses the propensity score matching method (PSM) and the double difference model (DID) to study the impact of Internet use on enterprise innovation. The results show that Internet use can significantly promote the innovation level of China's manufacturing export enterprises, with obvious heterogeneity among regions. Compared with the central and western regions, the role of the Internet in promoting manufacturing export enterprises' innovation in the eastern region is more significant. Compared with the non-coastal regions, manufacturing export enterprises in the coastal regions benefit more. The promotion effect of the Internet on manufacturing export enterprises' innovation has a scale threshold and varies by ownership type: it is more significant on large and medium-sized enterprises, while state-owned enterprises have a higher innovation level than private enterprises. Mechanism analysis shows that Internet applications can, indeed, promote manufacturing export enterprises' innovation by reducing export costs and management innovation costs. This study contributes to the micro analysis from the perspective of dual heterogeneity of enterprises and regions, which provides new evidence for explaining the development of internet economy and enterprise innovation in developing countries.

Introduction

China is implementing an innovation-driven development strategy, striving to become an innovative country, and clearly emphasizes that the first driving force for the sustainable development of enterprises is innovation. However, the technological changes represented by electronic information and communication networks are changing with each passing day, bringing unprecedented challenges and opportunities to the enterprise innovation in traditional industries. In theory, manufacturing enterprises may face greater pressure when dealing with information technology, especially Internet changes, compared with enterprises in other industries. This signals that, as a large manufacturing country, China faces a key turning point of innovation transformation: promoting the innovation of manufacturing export enterprises is an important breakthrough in economic transformation, against a background of deepening openness to the outside world. With the advances of the Internet and globalization, domestic import and export enterprises that squeeze into the international market with low-cost advantages gradually

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lose their viability, while those that focus on a comprehensive level of innovation continue to expand their market share in the international market (Kee & Domestic, 2016). According to the digital China Development Report (2020), China's total digital economy ranks second in the world. The Internet has developed into a new power source for manufacturing innovation, having incorporated artificial intelligence technology into the production and operation of enterprises, and provided explosive digital information resources for them. According to the Report on Innovation and Development Results of Industrial Internet (2018–2021) released by China Industrial Internet Research Institute, China's "Comprehensive+Characteristic+Professional" Industrial Internet platform system is constantly improving, with more than 100 platforms with certain industrial and regional influence, 76.86 million sets of industrial equipment connected, 588,000 industrial mechanism models and 1.6 million service enterprises. Relying on the Internet for innovation and upgrading has become key for China's manufacturing export enterprises to survive and develop in the era of a digital economy. Therefore, clarifying the impact of the use of the Internet on the innovation of China's manufacturing export enterprises and the impact mechanism of the Internet for enterprise innovation from the micro level, and exploring the internal mechanism of the transformation and upgrading of China's manufacturing export enterprises under the new normal are the theme of this study.

Before the 21st century, China's economic development goal was to achieve rapid growth. With the popularization of the Internet, however, the direction of China's economic development turned to high-quality growth. By the end of 2021, the number of Internet users in China has exceeded 1 billion, with a growth rate of 15.6%, and the national Internet penetration rate has exceeded 80%. With the increasing penetration of the Internet in the economic field, the State Council pointed out, in the "Made in China 2025″ report, we should focus on improving the penetration and use of the Internet in the manufacturing industry. The proportion of Chinese manufacturing enterprises using the Internet for transactions increased from 7.2% in 2013 to 20.6% in 2021. Although the utilization rate of the Internet in manufacturing export enterprises' production and applications continues to improve, there remains ample room for improvement in the integration of the Internet and enterprises. In recent years, the uncertainty of competition and cooperation in Sino-US trade has increased. In view of China's increased export trade barriers, it is no longer feasible for manufacturing export enterprises to achieve sustainable economic development only through low tariffs. In the context of rising trade protectionism, focusing on an innovation drive is fundamental to overcoming the difficulties of survival, transformation, and upgrading for China's manufacturing export enterprises. The ultimate purpose of this study to demonstrate how to use the power of the Internet to overcome the trade contradictions and conflicts faced by export enterprises in realizing innovation, transformation, and upgrading; it provides a new solution for the sustainable development of China's manufacturing export enterprises and the healthy development of the trade economy under the new normal.

The remainder of this paper is structured as follows. The second part is literature review. The third part presents the theoretical mechanism and empirical hypothesis, while the fourth part deals with model setting, variable selection, and data processing. The fifth part contains an empirical analysis of the basic regression results, while the sixth part extends the mechanism test and heterogeneity analysis. The final part concludes, with policy recommendations.

Literature review

In recent years, due to the importance of digital economy and Internet economy, there are more and more documents focusing on the Internet and its impact on enterprise innovation. Exploring the existing research literature, this study finds that scholars have focused on the important role of the Internet in the trade economy. The literature has two main branches. One branch discusses the impact of the Internet on export enterprises as an industry. Freund and Weinhold (2002) first observed the great influence of the Internet on trade, and undertook an in-depth exploration. Meanwhile, their study caused an upsurge in academic research on Internet trade. The study concluded on a relationship between Internet penetration and trade exports through an analysis of United States data from 1995 to 1999: an increase in penetration rate of 10% would result in an increase of 1.7% in trade exports. Using the gravity model, Freund and Weinhold (2004) found that a 10% increase in the number of Internet hosts would raise export volume by 0.2%. Clarke and Wallsten (2010) classified countries according to their income levels, and examined the relationship between income level and Internet infrastructure. The authors found that the role of Internet penetration could raise developing countries' export volumes to developed countries, and vice versa. Gregori and Holzmann (2020) proposed that the business model in the Internet age satisfied customers' deep-seated needs. As an important channel for information dissemination, the Internet helps to stabilize the export expectations of enterprises, and to ensure their sustainable survival. Jin et al. (2019) incorporated the degree of Internet deepening and export agglomeration into a heterogeneous trade enterprise model simultaneously, and theoretically showed that Internet deepening was conducive to improving the sustainable survival of enterprises' exports. Cities with a higher degree of Internet deepening enjoyed higher export participation and export stability. Li and Du (2021) believe that the Internet can improve enterprises' ability to manage products, thus promoting innovation protection on the quality of their export products. Lancioni et al. (2000) claimed that the Internet could help reduce the communication cost between enterprises and suppliers, improve the service level, and reduce the logistics cost. Litan and Rivlin (2001)) analyzed the possible impact of the Internet on the economy, and found that the Internet could not only improve production efficiency, but could also significantly promote the efficiency of an enterprise's product R&D, supply chain management, and business operation. Dewan et al. (2003) found that the Internet reduced the cost of information search, enabled manufacturers to better understand consumers' needs, and thus provided customized products more consistent with consumers' preferences. Elia et al. (2021) found that the application of an e-commerce platform significantly improved the probability of enterprises' entering the export market and effectively promoted the expansion of enterprises' export scale. Sadaf et al. (2020) found that the penetration rate was directly proportional to the total imports and exports in GDP, and that the imports and exports would increase by 3.9% due to a unit percentage increase in the independent variable, penetration. Under the same circumstances, this impact was more obvious in middle and low-income countries. To study the impact of Internet facilities and penetration rate on enterprises, Liu and Qiu (2016) established several Internet indicators: the growth rate of wireless communication investment, the proportion of host tree, Internet bandwidth, and the proportion of people. They concluded that what drove the development of trade was not infrastructure, but penetration rate. Second, from the perspective of enterprises. Ricci and Trionfetti (2012) analyzed enterprise survey data obtained from the World Bank, and explored the relationship between the Internet and trade, from the perspective of enterprises. They found that, although the Internet could increase the probability of imports and exports, the trade intensity of enterprises' entering the market had little to do with the Internet. To better explore the relationship between the Internet and imports and exports, Sun (2021) set the proxy index for the Internet as the number of bilateral and two-way website links, and then discussed it, pointing out that the development of the Internet could prolong the export time and increase the export probability of enterprises, thus improving the export expansion margin and intensive margin and reducing the export price.

Consequently, the number of exports increased. Digital, networked, and intelligent technological reforms can significantly promote the status of the global value chain and upgrade resource allocation (Hansen & Bøgh, 2021).

Another issue to explore is the impact of the Internet on the innovation of export enterprises. The rapid development of the Internet has a growing impact on the real economy: for example, the number of web pages had reached 335 billion by the end of 2021, while the number of Internet users had reached 989 million, China's digital economy reached 45.5 trillion yuan, accounting for 39.8% of GDP. The Internet can promote resource replacement and export enterprise innovation in three ways, resulting in economic changes: reducing the cost of production and R&D, reducing the cost of information communication to increase interaction and communication among enterprises, and improving the effect of technology spillover. The information is open and transparent, and can be searched independently, thus making competition between enterprises fair, promoting the development of new products, the delisting of old products, and resource replacement between products. Yang et al. (2022) explores the relationship between broadband internet and enterprise innovation using the change in market concentration caused by the North −South separation reform of China Telecom in 2002 as an instrumental variable, the results show that in general, 1% increase in broadband internet access results in a 1.395% increase in the number of corporate patents. The Internet makes enterprises compete fairly through information disclosure, promotes the development of new products and delisting of old products, and promotes enterprises' technological innovation. Through an analysis of global cases, a study found that e-mail could increase the export probability of enterprises by 31% (Vaio et al., 2021). The number of enterprises in Asia and sub-Saharan Africa has increased due to the development and popularity of e-mail and websites. Enterprises' exports and imports have increased rapidly (Li and Tan, 2022). Furthermore, there are such cases in China, in which e-commerce drives enterprises' exports and the Internet usage has a statistically significant and negative impact on farmer SFPs (Ueasangkomsate, 2015), however, there remains a large gap in the research on "Internet innovation" (Li et al., 2021). Fernandes et al. (2019) found, the Internet could promote the integration and sharing of cross-regional innovation resources to obtain higher returns to scale in the new economic structure. Wang et al.'s (2020) analysis and investigation, based on China's provincial-level data, found that the growth and temporal and spatial correlation of the Internet could make faster, more stable, and greater progress in regional innovation. Feng et al. (2019) used data on China's imported manufacturing enterprises to investigate the impact of the Internet on enterprise innovation, and its mechanism. The study found that the use of the Internet significantly improved the innovation level of China's manufacturing import enterprises, and laid a research foundation for the Internet and export enterprises' innovation.

Although the above literature has laid a foundation for innovation research on the Internet and export enterprises, it has not been refined to focus on manufacturing export enterprises. Most of the existing literatures focus on the analysis of the impact of the Internet on the macro economy, and there are few studies on the micro economy. Thanks to the improvement of the enterprise-level database and the reduction of the difficulty of data acquisition, the research on the impact of the Internet on the development of enterprises is increasing. Based on the national conditions of China's large manufacturing industry, this study discusses the impact of the Internet on the innovation of China's manufacturing export enterprises on a micro level. In addition, most of the existing literature focuses on the impact of the Internet on the economic growth of a single, given enterprise, and does not deeply explore the mechanism of the impact on the innovation of China's manufacturing export enterprises. Compared with the existing literature, the marginal contribution of this study lies in the following: (1) Using the matched data in China's industrial enterprise, customs and patent databases, based on the dual heterogeneity of regions and enterprises, this study discusses the relationship between the Internet and innovation of China's manufacturing export enterprises from a micro perspective, to offer new solutions pertaining to the innovation and upgrading of China's manufacturing export enterprises. (2) This study empirically tests the theoretical proposition using the propensity score matching model; it provides empirical evidence for enterprises to innovate, from the perspective of the Internet, and to realize industrial transformation and upgrading, and is of great practical significance in improving China's low-end locking in the global value chain system. (3) The study analyzes the intermediate mechanisms of "transaction cost saving effect", "enterprise resource integration effect" and "knowledge creation effect", it summarizes the possible mechanism of the impact of the Internet on enterprises, promotes enterprise innovation by reducing enterprise export costs and management expenses, and theoretically contributes to improving the innovation research of export enterprises.

Theoretical mechanism and empirical hypothesis

The "Internet plus" trade mode is an innovative method adopted by enterprises in their internal management. Essentially, it is a form of comprehensive improvement in services (Abouzeedan & Busler, 2007; Zhang et al., 2018). The Internet can effectively reduce the communication and transaction costs of trade between enterprises, improve enterprises' acquisition and integration ability in respect of relevant material resources, and cover operations, production, and innovation. Driven by the development of the Internet, social subjects have increasingly carried out enterprise innovation. The Internet has become a new channel for these subjects to learn new knowledge and improve their technological innovation ability. Through technological innovation, enterprises gain the sovereign mastery of technology and improve their innovation in technology, products, and even strategies, which together constitute the common innovation management of socialism and enterprises. Therefore, this study summarizes the mechanism of the impact of the Internet on the innovation of manufacturing export enterprises as the transaction cost saving, enterprise resource integration, and knowledge creation effects.

Transaction cost saving effect

In international trade, transaction cost refers to the costs and expenses incurred by enterprises in cross-border transactions. It is an important factor in the status of enterprises or countries in the global value chain. With the explosive development of Internet information technology, it is particularly important to consider the impact of the Internet on manufacturing enterprises' import and export trade from the perspective of transaction costs (Zhu et al., 2020). Generally, the main reasons for the high cost of enterprise information transactions are language, culture, and export trade barriers. Therefore, enterprise managers should focus on the role of information because the policy means to reduce information and transportation costs are completely different. With the popularization of Internet technology in the field of trade, the World Trade Organization and major trading countries are gradually paying attention to and promoting the realization of world trade facilitation, to reduce information transaction costs. The Internet connects global information through a network, builds a bridge to promote global information sharing, and improves the matching degree between consumer demand and producer supply, to reduce enterprises' information collection costs(). Relevant experts have summarized the cost reduction of enterprises affected by the Internet into five aspects: replication, search, transportation, verification, and tracking costs. The efficiency of information exchange and information matching between the two sides of a transaction is affected by the search cost. Acquiring experience and knowledge in

the supply of public goods is affected by the cost of replication, while developed information technology reduces the communication and replication costs; the consequent low-cost expenditure encourages enterprises to invest more funds in product innovation, and gradually replaces transaction costs with export costs (Liu & Li, 2021). Transaction cost reduction saves enterprises' funds and increases R&D investment and production innovation. Accordingly, the following hypothesis is proposed:

Hypothesis 1. The Internet can reduce manufacturing enterprises' transaction costs and promote their innovation.

Effect of enterprise resource integration

Enterprise resource-based theory deals with a collection of enterprise resources and explains enterprises' core competitiveness. Integrating an enterprise's various resources can give play to its advantages and improve its core competitive advantage. Resource-based theory turns the research perspective of an enterprise's transaction costs to a perspective of its internal advantages, comprehensively analyzes its resource advantages, and provides a theoretical basis for the analysis of its internal management (Yadav, 2014). In the process of enterprise innovation, the most important driver is the integration of the resources of knowledge and thought. Most of the original literature on the generation of innovation regarded innovation as a random behavior under a given exogenous distribution, and did not thoroughly consider its generation process. In the subsequent research and thinking on innovation, people make difference on the technological revolution through the generation of new ideas and knowledge. Generally, the reason for producing new thought is mainly to practically solve problems. Based on the above analysis, enterprises can improve innovation efficiency through two aspects: First, pay the cost of collecting information to improve the frequency of thought exchange with the outside world. The second step is to obtain the necessary resource information through certain channels, to improve their own knowledge and experience. Because the Internet itself has the advantages of digitization and informatization, enterprises can more rapidly screen and integrate the information they need by using the advantages of Internet resource sharing and resource classification. On the one hand, the Internet reduces the time cost of information collection and integration; on the other, the massive Internet information database provides enterprises with a source of professional knowledge. It is conducive to enterprises' learning advanced knowledge, skills, and technological innovation, and to their improving their production and operation efficiency and innovation ability. The characteristics of Internet sharing, intelligence, digitization, networking, and innovation can significantly encourage enterprises to learn external knowledge and introduce advanced technology, to promote enterprise innovation. Therefore, the following hypothesis is proposed:

Hypothesis 2. The Internet can promote manufacturing export enterprises' innovation by improving the efficiency of their resource integration.

Knowledge creation effect

Knowledge-based theory (KBT) points out that the goal of enterprises is to realize the creation, integration, and transfer of knowledge to establish and develop sustainable competitive advantage. Similarly, as an intangible resource, knowledge is more likely to produce competitive advantage than tangible resources. KBT emphasizes the competitive advantage obtained by having unique resources from a static point of view, and highlights the importance of organizational learning and knowledge integration (Nisula et al., 2022). KBT holds that this kind of dynamic theory regards an enterprise as the main body that adapts to the changing environment through its own dynamic ability, that is, the integration and reconstruction of the enterprise to cover the comprehensive competitiveness of internal and external scenes. Any innovation in an enterprise represents an input (such as new thinking, construction, etc.) and output (such as product novelty) of knowledge. As the key driving force of enterprise innovation activities, knowledge is also the source of productivity development and economic growth. As an important enterprise resource, professional knowledge attached to key strategic development practice has great significance. Professional knowledge is divided into invisible and explicit professional knowledge (Bouncken et al., 2021). The key direction of knowledge theory is how to obtain brand-new professional knowledge and gradually develop, absorb, and spread it. The fundamental of technological innovation is the improvement and reform of the production process, centered on professional knowledge resources. After absorbing and integrating internal and external reform and innovation resources, a company fully ensures its first-hand advantage in market competition in the trading market. Due to the heterogeneity and diversity of professional knowledge, the use requirements and search for heterogeneous professional knowledge also reflect the uniqueness and heterogeneity of knowledge as a resource. Enterprises improve their innovation ability by absorbing and digesting professional knowledge; the knowledge mastered by enterprises lays the foundation for further innovation and upgrading. Accordingly, the following hypothesis is proposed:

Hypothesis 3. The Internet can promote enterprise knowledge creation and then promote enterprise innovation.

The logical relationship between the theoretical mechanism and related effects discussed above can be shown as follows (Fig. 1).

Model setting, variable selection, and data processing

Model setting

This study focuses on the mechanism of the impact of the Internet on the innovation of China's manufacturing export enterprises. However, indeed, whether an enterprise uses the Internet is not random. Enterprises with good performance (such as large-scale enterprises with high productivity) may tend to use Internet technology and have stronger innovation ability; thus, the sample selected in this study may be endogenous, with selection errors. The criteria for choosing whether an enterprise uses the Internet are likely to affect the innovation level of the enterprise. Therefore, to overcome the above problem, this study uses the propensity score matching method (PSM) to conduct the empirical research.

The double difference (DID) model requires conformity to the common trend hypothesis in the ideal state; however, it is usually difficult for actual observation data to meet the requirement. The PSM-DID method can effectively solve this problem, that is, the PSM is used to match and screen the sample observations before the DID model. Therefore, to deal with and solve the endogenous problem created by sample selection errors, and to meet the common trend hypothesis required by the DID model, this study uses existing research for reference and selects the following matching variables: enterprise age (*age*), which is expressed as the logarithm of "research year - enterprise establishment year +1"; the square term of an enterprise's age (*age2*), which automatically generates enterprise measure; the overall scale of an enterprise (*scale*), expressed as the logarithm of the total number of an enterprise's staff in previous years; the asset liability ratio (*alr*), which is determined as the logarithm of the ratio of the total amount of an enterprise's external liabilities to the total assets; capital intensity (*klr*), expressed as the logarithm of an enterprise's total fixed capital storage compared with the average total number of employees in a year; set multiple virtual variables of industry (GB / T binary code classification standard) and region (eastern, central and western, and coastal classification standard), represented by industry and region, respectively, to control for the characteristics of industry and region. Propensity matching is performed using these variables. The internet binary virtual variable, *inter*, is constructed

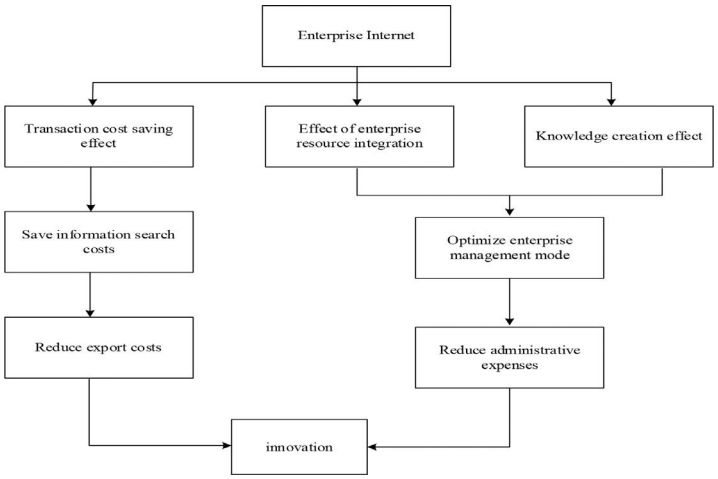

Fig. 1. Mechanism of the Internet in manufacturing export enterprises' innovation.

as the main explanatory variable in the PSM model. *inter* = 1 means that the enterprise using the mailbox or having a web page is the enterprise using the Internet, otherwise *inter* = 0. In the study's analysis framework, the experimental group comprises enterprises that use the Internet for the first time, while the control group comprises enterprises that have never used the Internet. In addition, the binary dummy variable, $t = \{0,1\}$, is set: $t = 0$ represents the period before the enterprise uses the Internet (web page or mailbox), while $t = 1$ represents the period after the enterprise has adopted the Internet (web page or mailbox). The benchmark model used for the estimation is as follows:

$$\ln inno_{it} = \beta + \beta_1 T \cdot \text{inter}_{it} + \beta_2 X_{it} + \eta_i + \eta_t + \varepsilon_{it} \quad (1)$$

In the model, *inno* is the enterprise's innovation situation; *inter* is a binary virtual variable, indicating whether the enterprise uses the Internet. When an enterprise uses the Internet, the value of *inter* is 1, while the value of *inter* is 0 when the enterprise does not use the Internet; *i* represents the enterprise, and *t* represents the year; *X* is a series of variables that may have an impact on innovation or Internet use: if these control variables are ignored, the estimation results may be biased; η_i and η_t are enterprise fixed effects and year fixed effects, respectively; ε represents the random error term. β_1 represents the impact of Internet use on enterprise innovation: $\beta_1 > 0$ indicates that the use of the Internet promotes the innovation level of the enterprise, while $\beta_1 < 0$ indicates the use of the Internet to improve the innovation level of enterprises.

Variable selection

(1) Explained variable

The explained variable in this study's model is the innovation of export enterprises (*inno*). The existing literature mostly selects the output value or R&D cost of new products in the database of Chinese industrial enterprises to measure enterprises' innovation level. Generally, although the output value of new products reflects enterprises' R&D achievements, many enterprises misrepresent the output value of new products to meet the government's innovation requirements, while the data are not strongly reliable. Although, generally, the more R&D expenditures are invested by enterprises, the more innovative the achievements will be, many enterprises innovate for the sake of innovation, to obtain national innovation subsidies, while the results are not very ideal. Additionally, many enterprises experience long R&D cycles and time lags. Therefore, there remain considerable differences in choosing new product output value and R&D expenditures as indicators of enterprise innovation. Referring to the practice of the existing literature (Sakaki & Jory, 2019), this study selects patent authorization, which is an indicator that can better reflect the innovation output of enterprises, as the explanatory variable. The patent authorization reflects the transformation of achievements accumulated by the enterprise in technology research and development and patent application for many years. It has an important reference significance for examining the innovation ability, innovation input and innovation achievements of enterprises.

(2) Explanatory variables

The core explanatory variable in the model is whether enterprises use the Internet(*inter*), which is mainly consistent with previous scholars' methods, and regards the use of enterprise websites and mailboxes in China's industrial enterprise database as an alternative indicator. However, the following situations cannot be ruled out: some enterprises do not use e-mail or web pages, but report the use thereof at the time of declaration. Considering that enterprises generally overstate the cost to reduce or exempt taxes, while the use of websites and e-mail has no impact on the enterprise cost, compared with other agency indicators, the information forgery associated with this indicator is not high. Another issue is that some enterprises have web pages and mailboxes but rarely use them, or use them but do not report them. The conclusion will underestimate the impact of the Internet on enterprise innovation. If the impact is underestimated, the promotion effect of the Internet on enterprise innovation remains significant, which can only indicate that it would be more significant if it were not underestimated. Therefore, based on the literature of Nguyen et al. (2020), it is reasonable to choose whether an enterprise uses a website or mailbox as the proxy variable for the core explanatory variable. Considering that an enterprise is unlikely to deactivate its website or e-mail after establishing them, if an enterprise uses a website or e-mail in a certain year, the virtual variables for that year and subsequent years are set to 1; if the enterprise does not use a web page or mailbox, the variables are set to 0; If the web page and mailbox data in the database are missing or absent, they will be replaced by 0.

(3) Control variables

Based on Paunov and Rollo's (2016) research methods, the control variables in this study are those that affect not only the core explanatory variable, enterprises' use of the Internet, but also enterprises' innovation level, the explained variable. The following control variables were selected: enterprise scale (*scale*), which has a significant impact on whether an enterprise uses the Internet and innovation, expressed as the logarithm of the average annual number of

employees, and enterprise age (*age*), enterprise experience, history, and culture, which have a significant impact on enterprise innovation (therefore, it is necessary to use the opening year's figure minus the survey year's figure when taking the natural logarithm as the important control variable of enterprise age), enterprise capital strength (*capital*), expressed as the logarithm of an enterprise's fixed capital stock divided by the number of its employees, enterprise asset liability ratio (*alr*), expressed as the logarithm of total liabilities divided by total assets, and enterprise nature, including foreign-funded enterprises (*foreign*) and state-owned enterprises (*ownership*). Unless otherwise specified, the same control variables are added to the regression analysis in other parts of this paper. For the convenience of observation, we give the definitions of all variables (Table 1).

Data source and processing

(1) Data sources

The sample information mainly comes from the following three databases.

① China industrial enterprise database: The database covers relevant information on all state-owned and non-state-owned enterprises with a total output value of more than 5 million yuan, including enterprise ownership, export volume, balance sheet, and fixed assets. For this study, the relevant information is on the use of websites and mailboxes by the Chinese manufacturing export enterprises in the database.

Table 1
Variable definition.

variable	variable symbol	variable definition
explained variable	*inno*	number of patent applications per year
core explanatory variable	*inter*	if mailbox or Internet is used in a year, the year and subsequent years will be 1, otherwise 0 will be taken
other variables	*cost*	export cost = ln{export delivery value/gross industrial output value ×(administrative expenses+financial expenses + sales expenses + wages payable in main business + welfare expenses payable in main business)}
	manage	administrative expenses = ln (total administrative expenses of the enterprise / employees)
	age	enterprise age = ln (year of business - year of investigation + 1)
	scale	enterprise scale = ln (annual average number of employees)
	alr	asset liability ratio = ln (total liabilities / total assets)
	capital	capital intensity = ln (stock of fixed assets / employees)
	ipr	internet penetration rate = ln (Internet penetration rate of the province where the enterprise is located)
	ownership	dummy variable, state-owned enterprises take 1, otherwise take 0
	foreign	virtual variable, foreign-funded enterprises take 1, otherwise take 0

② China customs database: The trade mode and export products of manufacturing export enterprises can be obtained from the China customs database. The database classifies products based on the HS code and records each import and export trade in detail.

③ China patent database: This database mainly records the patent application registration after the patent system was implemented in China. It contains all the information on three patents: design, invention, and utility model patents. The database records various information that can reflect an enterprise's innovation in detail, mainly including the patent name, applicant, inventor, address, and other information for each patent, which accurately reflect an enterprise's innovation behavior.

(2) Data processing and descriptive statistics

Considering the availability of data, the sample period is from 2004 to 2010, while the Chinese industrial enterprise database starts counting enterprise web pages from 2004. Therefore, the data selection starts from 2004 and, because the enterprise mailbox web page information in the Chinese industrial enterprise database is only updated to 2010, the deadline year is 2010. For the industrial enterprise and customs databases, reference was made to previous studies (Dong et al., 2014; Liu et al., 2018) in comprehensively handling abnormal values in the data: deleting the enterprise observations lacking any one item or with zero values in the total industrial GDP, fixed assets, total number of employees, and enterprise fixed assets, and removing a few unscientific observations (Tang et al., 2019), such as when the total number of employees was less than 8, the total fixed asset value was higher than the total asset value, the total economic income or export volume was lower than 0, etc. In this study, the author selects enterprises based on their foreign export volume and foreign export delivery volume. In the customs database, enterprises with a total export amount higher than zero, or with a foreign export delivery value higher than zero in the industrial enterprise database, are foreign export enterprises. After matching an enterprise's name with the Chinese enterprise database postal code, the enterprise's name is directly identified by the postal code, using the Chinese enterprise database's seven-digit method. For the Chinese patent database, after matching the enterprises' names with the postal codes, the data were matched and merged into unified panel data; a total of 22,167 enterprises and 44,478 observations were obtained. The descriptive statistics of the main variables are shown below (Table 2).

Empirical analysis

Benchmark regression analysis

Following Liu and Rosell's (2013) methods, we examined the processing and use of the PSM method, and selected the nearest-

Table 2
Descriptive statistics.

variable	sample size	mean	sd	min	max	p50
inno	44,470	7.39	72.5	0	6364	2
inter	44,470	0.41	0.49	0	1	0
scale	44,470	5.80	1.24	0	12.2	5.71
manage	44,466	30.04	53.37	−96.32	3286.89	17.53
age	44,470	11.51	11.09	0	142	9
klr	44,409	4.07	1.33	−5.63	12.19	4.13
alr	44,470	−0.80	0.86	−13.43	5.8	−0.6
ipr	44,470	31.03	15.54	2.51	62.08	29.23
ownership	44,470	0.03	0.17	0	1	0
foreign	44,470	0.13	0.33	0	1	0

neighbor matching method, using a ratio of 1:5. Given the different Internet environment every year, there may be significant differences in the impact on innovation; therefore, year-on-year matching was used to find the control group observations for each experimental group observation.

In the benchmark regression, we use the year-on-year matching data from 2004 to 2010, and use the nearest-neighbor matching method to match the processed observations with the five control observations with the nearest score for each experimental group, based on the ratio of 1:5. There are 15,357 enterprises using the Internet in the processing group, that is, *inter* = 1. Using the PSM method, the five observations closest to the processing group's score are selected from the enterprises that have never used the Internet, the control group, i.e. *inter* = 0. Taking 2004 as an example, we first calculate the score value for each sample enterprise that uses the Internet; we then find five control observations with the nearest score value to each processing group observation, based on the matching score value, and finally remove the matching to yield the enterprise with the successful matching. For manufacturing export enterprises in other years, from 2004 to 2010, the same method was used to find the five control group enterprises with the latest scores for each treatment group observation.

In the matching process, to ensure the reliability of the sample matching, the matching must meet the balance and common support hypotheses. The scores of most observations are within the common value range, and only a few extreme values are eliminated (Fig. 2). Therefore, the common support test is satisfied. In addition, in the balance test, there is no significant difference between the control and experimental groups. We can see the balance test results for the experimental and control groups before and after matching (Table3). The accompanying probability of t after matching is greater than 10%, which indicates that there is no significant difference between the experimental and control groups after PSM matching, while none of them passed the significance test.

From Table 3, the results for each matched variable are ideal, there is no large standard deviation, while the results after matching are less than the standard deviation before matching. More intuitively, we give the standard deviation test chart for PSM matching (Fig. 3). The variable deviations after matching are close to 0, while the absolute values are less than 5%. From the image, the mean deviation of each variable after matching is small, and can be used for the subsequent empirical test.

In order to observe the distribution of variables more clearly, the kernel density diagram of the propensity scores of the experimental and control groups before and after matching, while the score distribution of the matching variables is given (Fig. 4). From the figure, the coincidence area of the experimental and control groups before matching is significantly smaller than that after matching, while there is a large coincidence area in the nuclear density diagram of the tendency score values of the two groups before and after matching, indicating that the matching meets the requirements of the common support hypothesis.

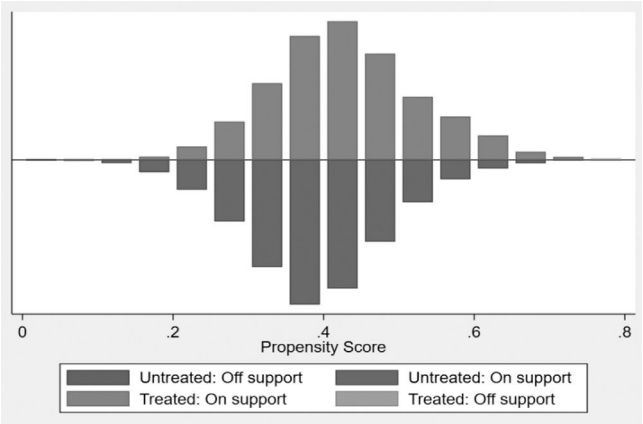

Fig. 2. Common value range of propensity score.

Based on the matching data, a benchmark regression test is performed on whether the Internet can promote innovation, controlling for the time and enterprise fixed effects (Table 4). Columns (1) and (2) are the benchmark regression results of the 1:5 nearest-neighbor matching with a radius of 0.05, without and with adding the control variables. The coefficient of the *t·inter* interaction term is always significantly positive at the level of 1%, which means that Internet application has a significant positive promoting effect on the innovation of China's manufacturing export enterprises, Columns (3) and (4) is the benchmark regression results of the one-to-five nearest-neighbor matching with a radius of 0.01, without and with adding control variables. The results show that, whether the matching radius is 0.05 or 0.01, the *t·inter* interaction term coefficients are significantly positive at the 1% level, which further confirms Hypothesis 1.

In combination with the background of China's economic development, the Internet economy and industrialization are more closely combined. In order to enhance their competitiveness, enterprises will continue to improve the application ability of the Internet, and apply the Internet to technological innovation, to accelerate knowledge spillover and technological innovation. The benchmark regression results of this study verify the above views and conform to the economic reality.

Robustness test

The robustness test adopts two methods: one is to change the matching proportion, while the other is to change the matching mode. To change the matching ratio means to adjust the original 1:5 matching ratio or the original matching method to 1:1 and 1:3. Changing the matching method means replacing the nearest-neighbor matching method with the kernel matching method to match the corresponding control observations.

(1) Change matching proportion

In order to ensure the reliability of the regression results, we change the matching ratio to develop a new test and give the results (Table 5). Columns (1) and (2) are the regression results of the nearest-neighbor matching based on a ratio of 1:1. The matching radius is 0.05. Column (1) does not add control variables, while Column (2) does. Columns (3) and (4) are the regression results of the nearest-neighbor matching based on a ratio of 1:1 matching. The matching radius is 0.05. Column (3) does not add control variables, whereas Column (4) does. From the table, the regression results of the 1:1 matching without control variables are significantly positive at the level of 5%, while in other cases, the coefficient of t·inter is significantly positive at the level of 1%. Therefore, the regression results from changing the matching proportion also support Hypothesis 1: Internet application has a positive impact on China's manufacturing export enterprises.

The sample size decreases after matching. To test whether the regression results are robust, the study expands the original nearest-neighbor matching ratio of 1:5 to 1:8 and 1:10. The regression test shows that the results do not change significantly, indicating that the benchmark regression results are robust.

(2) Change the matching method

Benchmark regression uses nearest-neighbor matching. To reduce the bias of the DID method and the systematic difference of the

Table 3
Balance test results for PSM.

variable	matching	mean value experience group	control group	standard deviation(%)	Reduction of standard deviation(%)	t statistic	*t*-test companion probability
scale	before	5.92	5.73	15	89.7	15.83	0.00
	after	5.92	5.94	−1.5		−1.49	0.14
manage	before	32.60	27.79	9.5	98.3	9.92	0.00
	after	32.60	32.68	−0.2		−0.15	0.88
age	before	12.80	10.65	19	81.9	20.45	0.00
	after	12.80	13.19	−3.4		−2.99	0.22
age2	before	6.05	5.42	19.5	83.1	20.84	0.00
	after	6.05	6.16	−3.3		−3	0.28
klr	before	4.16	4.02	10.6	94.1	11.16	0.00
	after	4.16	4.17	−0.6		−0.63	0.53
alr	before	−0.75	−0.79	5.2	91.5	5.39	0.00
	after	−0.75	−0.75	−0.4		−0.46	0.65
ipr	before	28.27	30.16	−12	89	−12.64	0.00
	after	28.27	28.06	1.3		1.31	0.19
ownership	before	0.04	0.02	10	80.2	10.70	0.00
	after	0.04	0.05	−2		−1.70	0.65
foreign	before	0.11	0.13	−8.4	98	−8.75	0.00
	after	0.11	0.11	0.2		0.17	0.87

change trend, and to ensure the robustness of the regression results, the matching method is changed to the kernel matching method to test the robustness. The test results are shown in the following table (Table 6). Columns (1) and (2) are the benchmark regression results of the 1:5 nearest-neighbor matching, while Columns (3) and (4) are the results of the kernel matching estimation. We find that, after changing the matching method, the coefficient of *t·inter* remains significantly positive at the level of 1%, which supports the previous analysis results.

Mechanism test and heterogeneity analysis

Mechanism test

Referring to the methods of the existing literature (Chiu & Lin, 2022), the mechanism test uses the intermediary effect test. The intermediary variables are export cost and management cost. For the test, Models (2) and (3) are set as follows:

$$\ln inno_{it} = \beta + \beta_1 t \cdot \text{inter}_{it} + \beta_2 X_{it} + \eta_i + \eta_t + \varepsilon_{it} \quad (2)$$

$$\ln inno_{it} = \beta + \beta_1 t \cdot \text{inter}_{it} + \alpha_1 \text{cost}_{it} + \alpha_2 manage_{it} + \beta_2 X_{it} + \eta_i + \eta_t + \varepsilon_{it} \quad (3)$$

Where i represents an enterprise, t represents year, *cost* represents the export cost in the model, and *manage* represents an enterprise's management expense. X_{it} denotes a series of control variables that can affect both enterprise innovation and enterprise use of the Internet, which is consistent with the types of variables in the benchmark regression.

(1) Inspection of export cost intermediary mechanism

We give the test results of the intermediary effect test of whether enterprises' use of the Internet promotes innovation by reducing the

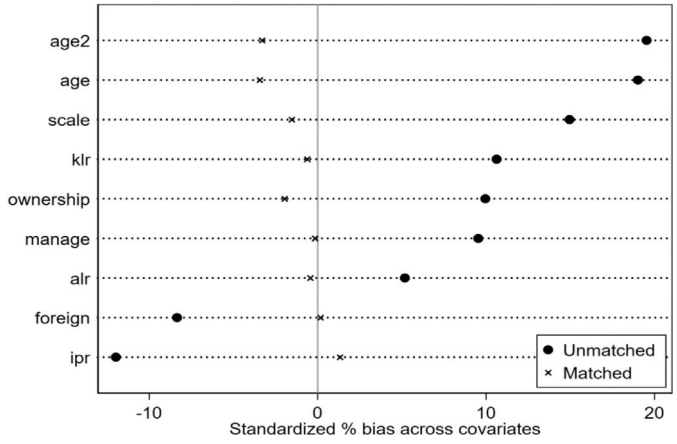

Fig. 3. Standard deviation test before and after PSM.

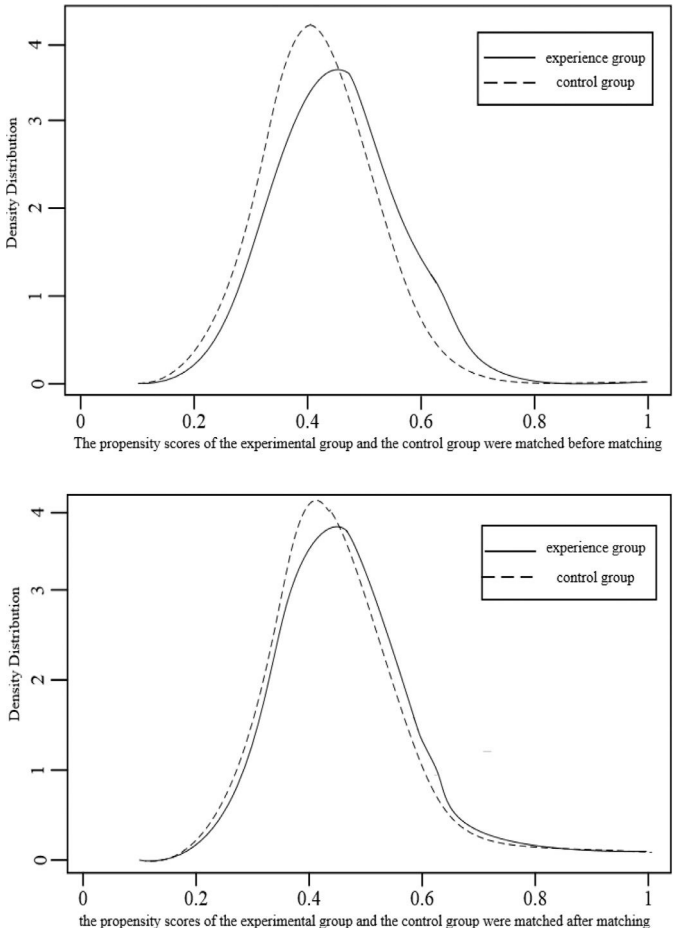

Fig. 4. Propensity scores of the experimental and control groups before and after PSM.

Table 4
Benchmark regression results.

variable	(1) *lninno*	(2) *lninno*	(3) *lninno*	(4) *lninno*
t·inter	0.162***	0.157***	0.162***	0.157***
	(0.026)	(0.026)	(0.026)	(0.026)
scale		0.208***		0.208***
		(0.015)		(0.015)
manage		0.001***		0.001***
		(0.000)		(0.000)
age		0.018***		0.017***
		(0.004)		(0.004)
age2		−0.075***		−0.075***
		(0.014)		(0.014)
klr		0.031***		0.031***
		(0.010)		(0.010)
alr		−0.020		−0.019
		(0.014)		(0.014)
ipr		−0.004***		−0.004***
		(0.001)		(0.001)
ownership		−0.071		−0.076
		(0.088)		(0.088)
foreign		0.003		0.002
		(0.042)		(0.042)
time fixed effect	yes	yes	yes	yes
firm fixed effect	yes	yes	yes	yes
constant term	1.201***	0.093	1.200***	0.095
	(0.016)	(0.108)	(0.016)	(0.108)
N	45,485	45,485	45,450	45,450
R^2	0.003	0.013	0.003	0.013

Note: The values in brackets are the clustering robust standard errors corresponding to the T value. ***, **, and * denote significant coefficients at the significance levels of 1%, 5%, and 10%, respectively.

export cost of enterprises (Table 7). Through processing, the Sobel test p-value of the intermediary effect is 0.0002, less than 0.05, indicating that the intermediary effect is established; The calculated mediating effect accounts for 19.82% of the total effect. First, the intermediary mechanism test is conducted when the control variable is not added. Column (1) is the result of the benchmark regression. The coefficient of the enterprise innovation is significantly positive. Column (2) shows that, after adding the export cost variable, the enterprise innovation coefficient drops sharply from 0.162 to 0.105, while the export cost coefficient is also significantly positive. It shows that enterprises using the Internet will indeed improve the innovation of their manufacturing exports by reducing their export costs.

Columns (3) and (4) are the intermediary mechanism test after adding control variables. The third column is the result of the benchmark regression, while the coefficient of *did* is significantly positive. In the fourth column, after adding the export cost variables, the innovation coefficient decreases significantly from 0.157 to 0.101, while the coefficient of export cost is 0.027, which is significantly positive.

Table 5
Regression results from changing the matching proportion.

variable	(1) *lninno*	(2) *lninno*	(3) *lninno*	(4) *lninno*
t·inter	0.084**	0.091***	0.148***	0.149***
	(0.035)	(0.035)	(0.028)	(0.028)
control variables	yes	yes	yes	yes
time fixed effect	yes	yes	yes	yes
firm fixed effect	yes	yes	yes	yes
constant term	1.175***	0.006	1.194***	0.026
	(0.021)	(0.141)	(0.017)	(0.116)
observed value	31,368	31,368	40,883	40,883
numberofid1	15,357	15,357	19,400	19,400
R^2	0.004	0.012	0.003	0.012

Note: The values in brackets are the clustering robust standard errors corresponding to the T value. ***, **, and * denote significant coefficients at the significance levels of 1%, 5%, and 10%, respectively.

Table 6
Regression results after changing the matching method.

variable	(1) *lninno*	(2) *lninno*	(3) *lninno*	(4) *lninno*
t·inter	0.162***	0.157***	0.182***	0.178***
	(0.026)	(0.026)	(0.026)	(0.026)
control variables	yes	yes	yes	yes
time fixed effect	yes	yes	yes	yes
firm fixed effect	yes	yes	yes	yes
constant term	1.201***	0.093	1.211***	0.085
	(0.016)	(0.108)	(0.015)	(0.104)
observed value	45,485	45,485	48,227	48,227
R^2	0.003	0.013	0.003	0.013

Note: The values in brackets are the clustering robust standard errors corresponding to the T value. ***, **, and * denote significant coefficients at the significance levels of 1%, 5%, and 10%, respectively.

Table 7
Test results for the intermediary effect of export cost.

variable	(1) *lninno*	(2) *lninno*	(3) *lninno*	(4) *lninno*
t·inter	0.162***	0.105***	0.157***	0.101***
	(0.026)	(0.025)	(0.026)	(0.025)
lncost		0.053***		0.027***
		(0.006)		(0.007)
control variables	yes	yes	yes	yes
time fixed effect	yes	yes	yes	yes
firm fixed effect	yes	yes	yes	yes
constant term	1.201***	0.735***	0.093	−0.158
	(0.016)	(0.052)	(0.108)	(0.126)
observed value	45,485	35,527	45,485	35,527
R^2	0.003	0.006	0.013	0.015

Note: The values in brackets are the clustering robust standard errors corresponding to the T value. ***, **, and * denote significant coefficients at the significance levels of 1%, 5%, and 10%, respectively.

It may be concluded that Internet application can, indeed, promote enterprises' innovation of manufacturing exports by reducing export costs.

(2) Inspection of intermediary mechanism of management expenses

The intermediary mechanism is used to test whether Internet applications can reduce enterprise management costs. This intermediary mechanism promotes the innovation of China's manufacturing export enterprises. The test results are shown in the table below (Table 8). Columns (1) and (2) are the benchmark regression results

Table 8
Test results for the intermediary effect of management expenses.

variable	(1) *lninno*	(2) *lninno*	(3) *lninno*	(4) *lninno*	(5) *lnmanage*
t·inter	0.162***	0.097***	0.157***	0.096***	−0.134**
	(0.026)	(0.022)	(0.026)	(0.022)	(0.037)
lnmanage		0.028***		0.054***	–
		(0.009)		(0.011)	–
constant term	1.201***	1.086***	0.093	−0.040	0.191*
	(0.016)	(0.027)	(0.108)	(0.110)	(0.085)
control variables	yes	yes	yes	yes	yes
firm fixed effect	yes	yes	yes	yes	yes
time fixed effect	yes	yes	yes	yes	yes
observed value	45,485	45,440	45,485	45,440	45,485
Numberofid1	20,818	20,807	20,818	20,807	20,818
R^2	0.003	0.003	0.013	0.012	0.024

Note: The values in brackets are the clustering robust standard errors corresponding to the T value. ***, **, and * denote significant coefficients at the significance levels of 1%, 5%, and 10%, respectively.

Table 9
Regional heterogeneity test results.

variable	(1) east	(2) middle	(3) west	(4) coastal areas	(5) non coastal areas
t-inter	0.10***	0.07	0.02	0.14***	0.02
	(0.03)	(0.10)	(0.11)	(0.03)	(0.04)
control variables	yes	yes	yes	yes	yes
time fixed effect	yes	yes	yes	yes	yes
firm fixed effect	yes	yes	yes	yes	yes
observed value	39,796	3359	2330	28,260	17,225
R^2	0.01	0.02	0.02	0.01	0.02

Note: The values in brackets are the clustering robust standard errors corresponding to the T value. ***, **, and * denote significant coefficients at the significance levels of 1%, 5%, and 10%, respectively.

Table 11
Heterogeneity test results for enterprises with different characteristics.

variable	(1) state-owned enterprise	(2) foreign enterprise	(3) private enterprise
t-inter	0.13	0.07*	0.08**
	(0.13)	(0.04)	(0.04)
control variables	yes	yes	yes
firm fixed effect	yes	yes	yes
year fixed effect	yes	yes	yes
observed value	1681	21,281	22,523
R^2	0.06	0.02	0.01

Note: The values in brackets are the clustering robust standard errors corresponding to the T value. ***, **, and * denote significant coefficients at the significance levels of 1%, 5%, and 10%, respectively.

of the intermediary mechanism test without control variables. The coefficient of t-inter in Column (1) is significantly positive, while Column (2), with the results after adding the management expense variable, shows that the enterprise innovation coefficient drops sharply from 0.162 to 0.097, while the export cost coefficient is also significantly positive. It shows that the Internet will, indeed, improve enterprises' innovation of manufacturing exports by reducing their export costs.

Columns (3) and (4) are the intermediary mechanism test after adding the control variable. The coefficient of t-inter in Column (3) is significantly positive, while Column (4) shows the innovation coefficient after adding the management expense variable. The innovation coefficient decreases significantly from 0.157 to 0.096, while the coefficient of export cost is 0.054, which is significantly positive. Through processing, the Sobel test p-value for the intermediary effect is 0.0002, less than 0.05, indicating that the intermediary effect is established; The calculated mediating effect accounts for 19.82% of the total effect. From this, we can conclude that Internet applications can, indeed, promote enterprises' innovation of manufacturing exports by reducing management costs. For the sake of logical rigor, we also added the test of the relationship between the Internet and enterprise management expenditure. From the results in column (5) of Table 8, we can see that the use of the Internet has indeed reduced the management cost of enterprises, thus verifying the regression conclusion of the intermediary effect.

Heterogeneity analysis

(1) Analysis of regional heterogeneity

First, considering the heterogeneity of regional factors, this study divides the whole sample into three regions: eastern, central and western regions, and coastal and non-coastal regions, the results are shown in here (Table 9). Overall, the coefficient of t-inter in eastern and coastal areas is significantly positive at the level of 1%. Compared with the central and western regions, Internet applications have significantly promoted manufacturing export enterprises' innovation level in the eastern region. Possible reasons are the following: The eastern region has a high degree of marketization, a high level of economic development, and more complete enterprise production factors, while the use of the Internet makes the enterprise innovation environment and mode more ideal. The eastern region has convenient transportation; thus, most export enterprises operate in the east, which makes the eastern region more prominent in terms of innovation level. Similarly, compared with non-coastal areas, the economic development environment in coastal areas is relatively more conducive to innovation; thus, Internet applications can promote manufacturing export enterprises' innovation.

(2) Analysis of enterprise scale heterogeneity

Second, regarding the heterogeneity of enterprise-level factors, the sample is divided into large-scale, medium-sized, and small-scale enterprises, based on the number of employees. We give the results here (Table 10). The use of the Internet by large-scale and medium-sized enterprises plays a significant role in promoting enterprise innovation, and has little impact on small-scale export enterprises' innovation. Possible reasons are that, first, for small enterprises, the possibility of using the Internet is small, while the operating costs are relatively low. Second, the degree of specialization for enterprise management is lower than that in large-scale and medium-sized enterprises. Therefore, compared with small-scale enterprises, the impact of the Internet on the innovation level of large-scale and medium-sized enterprises is more obvious.

(3) Heterogeneity analysis of enterprise nature

Based on the variable nature of the enterprises, the samples are divided into state-owned, foreign-funded, and private enterprises. The regression results are shown here (Table 11). It is found that

Table 10
Heterogeneity test results for enterprises of different sizes.

variable	(1) Large scale enterprise	(2) Medium scale enterprises	(3) Small scale enterprise
t-inter	0.06	0.18***	0.03
	(0.07)	(0.05)	(0.04)
control variables	yes	yes	yes
firm fixed effect	yes	yes	yes
year fixed effect	yes	yes	yes
observed value	8429	14,750	22,306
R^2	0.03	0.01	0.02

Note: The values in brackets are the clustering robust standard errors corresponding to the T value. ***, **, and * denote significant coefficients at the significance levels of 1%, 5%, and 10%, respectively.

Internet use has less impact on improving state-owned enterprises' innovation level and more significant impact on improving private enterprises' innovation level. Although state-owned enterprises have advantages in capital and talents, compared with state-owned enterprises, private and foreign-funded enterprises have higher capital liquidity, a more flexible management system, and more ideal innovation space and environment. These factors may lead to a higher impact of Internet applications on improving private and foreign-funded enterprises' innovation level.

Conclusions and policy implications

Applying the PSM method on data from the China industrial enterprise, China customs, and China patent databases, this study uses the DID method to explore the impact of Internet use on the innovation of manufacturing export enterprises at the enterprise level, and theoretically analyzed the mechanism by which the use of the Internet affects the innovation capabilities of manufacturing export enterprises. Empirical analysis shows that internet use has significantly improved the innovation capabilities of Chinese manufacturing enterprises, but there are significant differences in different regions and ownership enterprises. The results of the regional heterogeneity test indicate that the Internet has a significant impact on manufacturing export enterprises' innovation in the eastern coastal area, which may be due to the ideal Internet development environment in the eastern coastal area. The test results for differently-owned enterprises show that Internet use more significantly improves private enterprises' innovation level. In addition, this study tests the possible mechanism through which the Internet promotes the innovation of manufacturing export enterprises. The results show that the Internet significantly improves enterprises' innovation ability through the two intermediary variables of export cost and management cost. Our research has rich policy implications.

First, the essence of the Internet lies in "interconnection." As a new technological infrastructure, it has become an indispensable part of society. It is a basic condition for enterprises to apply the Internet for entrepreneurship, develop the Internet economy, and expand foreign trade. Although the penetration rate of 55.8% in China exceeds the world average, there remains ample room for improvement, compared with the penetration rate of more than 80% in European and American countries. Therefore, the government should strengthen the network infrastructure to compensate for the existing problems in the Internet infrastructure, such as the "digital divide." The study has confirmed that Internet use and strengthening its penetration in social and production life are conducive to optimizing China's foreign trade structure and resolving the "new normal" problems in the field of foreign trade. In addition, we should also strengthen the technical cooperation between Internet technology and other fields, especially the technical integration with manufacturing and service industries, to give play to the spreading and driving role of the Internet in the field of foreign trade.

Second, the Internet has provided a new impetus for China's economic development. The term "Internet plus" has emerged, ushering in possibility and a powerful impetus for China's "Internet + export" economy. As a new trade mode, Internet plus exports can render resources more efficient globally, and provide a role for the market mechanism. Thus, transaction costs can be reduced, transaction efficiency can be improved, thus promoting trade development and economic growth, including the cross-border e-commerce mode. Under the current circumstances, the Internet is widely used as a carrier of data and information. Based on the advantages of the Internet and its significant achievements in promoting foreign trade, we should actively guide the development of a cross-border electricity supplier industry and establish a new trade mode of "Internet plus exports."

Third, we should accelerate the deep integration of the Internet plus manufacturing industry, especially in the high-tech industry. The Internet provides opportunities and ways for traditional manufacturing industries and small and medium-sized enterprises to explore foreign markets and improve their business level. Using the Internet can more effectively promote enterprise innovation and transformation, while the effect on private enterprises is the most significant. At present, most Chinese enterprises are in a bottleneck that is in urgent need of enterprise transformation and upgrading, especially for the manufacturing industry. Against the current background of world economic globalization and the general trend of the world Internet wave, if China seeks to develop the manufacturing industry, the country must humbly learn from foreign advanced experience, use Internet technology, improve the ability to use data and information, strive to improve the innovation ability of manufacturing export enterprises in the new scientific and technological revolution, and avoid being at a disadvantage in international trade; it must rid itself of the embarrassing situation of being at the low end of the global market division of labor. In addition, the government and enterprises must increase capital investment, use the funds for R&D, innovation, and production of high-end equipment, such as precision instruments and fine products; they must promote the development of Internet technology, strive for excellence in China's manufacturing industry in certain fields and areas of the global market, lead the world's development, and enter the high-end link in the division of labor in the global market.

To be frank, there is still much more detailed work to be done in this study. The use of the Internet only reflects one aspect of enterprise digitalization. There are many other factors worth our analysis, such as the use of artificial intelligence, industrial robots, etc. What impact these latest technologies will have on enterprise innovation deserves more systematic analysis.

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