Impact of the Internet on the exports in ocean-based manufacturing: Firm-level evidence from China

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ABSTRACT

Ocean-based manufacturing (OBM) is closely related to the advancement of information technology, and the dramatic expansion in Internet access necessitates an analysis of the Internet's impact on marine economy. Combining firm-level manufacturing census data with provincial-level Internet development data, this study is the first to examine how Internet penetration across China's provinces in the 1999–2007 period influenced exports in OBM. The results indicate that the Internet rollout boosted exports in OBM firms, showing a significant technology-driven effect. Furthermore, the effects of the Internet on micro-behavior differ significantly between OBM and non-OBM firms. For OBM firms, the results suggest that the main mechanism at work is a productivity effect rather than a scale effect, whereas the results for non-OBM firms suggest the opposite. This study also emphasizes the cross-regional and cross-industry heterogeneity in the effects. The heterogeneity analysis supports a greater impetus of the Internet on capital and technology-intensive marine industries and non-state-controlled OBM firms. Moreover, the improvement of Internet penetration can significantly promote participation in international trade by OBM firms in large- and medium-sized cities. Compared with the Bohai Rim Area, the southern regions, including the Yangtze River Delta and the Pearl River Delta, have shown more rapid growth in marine industries due to the Internet rollout.

1. Introduction

Oceans play a significant role in achieving sustainable development, economic growth, and livelihood. The ocean's economic value has gradually drawn worldwide attention (Bennett et al., 2019; Cisneros-Montemayor et al., 2021; Jouffray et al., 2020; Katila et al., 2019). China has a long coastline and a high level of economic development in its eastern coastal areas. Recently, the government has paid special attention to the development of China's marine economy; consequently, the terms "marine/ocean economy" or "blue economy" appear frequently in China's Five-Year Plans. Nevertheless, significant differences still exist in the definition, demarcation,

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Table 1

Categorization and definition of ocean-based manufacturing.

Category	Definition
Marine mineral and seafood processing industry	An industry formed by traditional resource-dependent processing enterprises, of which the production process mainly includes processing marine minerals, marine animals and plants, offshore oil and gas, and other marine resources.
Marine shipbuilding industry	An industry formed by the production of ocean going and coastal transport ships, as well as auxiliary ships.
Marine chemical industry	An industry refers to the production of primary processed products with substances directly extracted from seawater such as sea salt, bromine, potassium, magnesium, and marine algae as raw materials, as well as the production of processed products of sodium carbonate, bromine, and other elements.
Marine biomedical industry	An industry of extracting effective components from marine organisms and using biotechnology to produce biochemical drugs, health products, and genetically engineered drugs.
Marine power industry	An industry refers to power production using tidal energy, wave energy, thermal energy, ocean current energy, salt difference, wind energy, and other natural energy in the ocean, and sometimes nuclear power and thermal power generation using seawater cooling in coastal areas.

Note: The definition of marine industry refers to the Chinese national standard "Classification of Marine and Related Industries" (GB/T20794-2021) issued by the Standardization Administration of the People's Republic of China on December 31, 2021.

and quantification of marine economic activities across regions (Surís-Regueiro et al., 2013). The State Oceanic Administration of China has developed the industry standards for the marine economy in 2006 and updated them by 2021. Additionally, the National Development and Reform Commission and the Ministry of Natural Resources of China have issued a series of annual reports named *China Marine Economic Development Report*. Chinese academia has also responded, and many high-quality research findings on China's marine economy have emerged in academic circles (Shao et al., 2021; Wang, Lu, & Yin, 2021; Liu et al., 2021; Wang & Li, 2020). Firms are the primary players in the marine economy (Havice et al., 2021a, 2021b; Virdin et al., 2021). Nevertheless, most studies on China's marine economy are limited to provincial- or city-level data. Only a few studies have used firm-level data, such as Qi et al. (2020), who used the concepts of product space and product proximity to identify a list of marine-related products for 107 Chinese firms and their related industries. Additionally, most studies on blue product trade (Qi et al., 2021) or the marine industry are focused on seafood (Yang et al., 2020), with few focusing on ocean-based manufacturing (OBM).

The Internet potentially affects the marine economy (Chen, 2020). For instance, Twumasi et al. (2021) examined the role of the Internet in promoting the development of marine fisheries. In fact, OBM in China is continuously upgrading (Jin, 2020). Because of its close relationship with technology, OBM is highly influenced by the Internet. China has invested large amounts of money in developing Internet infrastructure, which has promoted the popularization and application of the Internet over the decades. China needs to rely on technological innovation to achieve sustainable economic growth (Lebel, 2008). In 2010, the Information Office of the State Council of China issued a white paper on *The Internet in China*.[2] It stated that since China's Internet access in the 1990s, the government devised a set of policies for Internet development. By the end of 2009, the Internet had reached 28.9% of China's total population, which was higher than the global average. Because Internet technology is a typical example of innovative technology, whether it is used in a manufacturing process or in foreign trade, it will become a major driving force in promoting enterprise export (Lee, 2011).

Since Freund & Weinhold, 2002 work, an increasing number of researchers are focusing on the impact of the Internet on trade (Paunov & Rollo, 2016; Ricci & Trionfetti, 2012). Recently, significant theoretical and empirical evidence on the role of Internet technology in promoting manufacturing exports has emerged. From the perspective of trade theory, the Internet facilitates business connections by lowering transaction costs in the international market more than in the domestic market (Varian et al. 2004).[3] Moreover, the rapid development of Internet technology may promote the prosperity of bilateral trade through two major channels: (1) the reduction of search costs and matching consumers and suppliers (Lendle et al. 2016; Wang & Li, 2017), and (2) the improvement of firm efficiency by learning about new technologies (Comin & Mestieri, 2018; Keller & Yeaple, 2013). Numerous scholars have empirically validated the Internet's export promotion effect using the gravity model and country-level bilateral trade data (Clarke & Wallsten, 2006; Freund & Weinhold, 2004; Lin, 2015; Leuven et al., 2018). Presently, studies are shifting the focus from a country- and province-level to firm-level analysis. From the perspective of microenterprise business behavior, the Internet improves the export scale, international competitiveness, and domestic value-added of export enterprises by improving the innovation capabilities of Chinese manufacturing import enterprises and optimizing the export models of export enterprises (Fernandes et al., 2019). However, direct evidence of the effect of Internet technology on the export-oriented marine economy, especially firm-level evidence, is still lacking.

This research primarily contributes in four ways. First, OBM exports are becoming increasingly important in the marine economy. Nevertheless, empirical studies exploring the driving forces of ocean-based firm export behavior are rare. Hence, for the first time, this study employs the empirical research method of Fernandes et al. (2019) and uses China's firm-level manufacturing census data and Chinese customs data to explore the role of the Internet in enhancing the development of the outward-oriented marine economy. Second, this study is the first to use a firm-level database to examine the operating behavior of OBM firms to support further research on the characteristics of marine economic development and such firms' operation and export behavior. By comparing the operation and export behaviors of the OBM and non-OBM firms, the special effect of new information technologies, such as the Internet, on the development of the marine economy, is discussed. Third, this study employs Fernandes et al.'s (2019) method for dealing with Internet

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[2] *Source*: The Information Office of the State Council of the People's Republic of China: The Internet in China, 2010.
[3] *Source*: World Bank: World Development Report 2016: Digital Dividends, World Bank Publications, 2016.
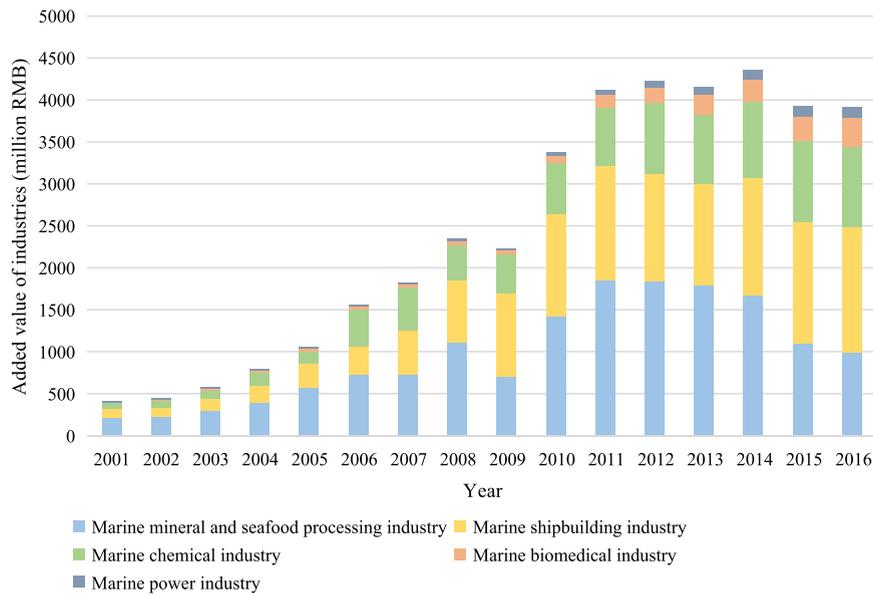
Fig. 1. Economic development of ocean-based manufacturing in China from 2001 to 2016. *Note*: Data were obtained from the State Oceanic Administration and EPS-DATA.
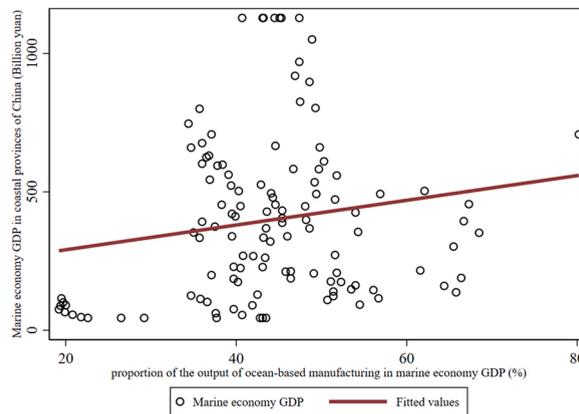

Fig. 2. Marine economy GDP in coastal provinces of China and proportion of the output of ocean-based manufacturing in marine economy GDP (2006–2016). *Note*: 1. Data were obtained from the State Oceanic Administration and EPS-DATA. 2. These are the results after removing 7% outliers (Marine economy GDP over 1,000,000 RMB in the coastal provinces of China).

data and attributes the export behavior of OBM firms and the corresponding Internet driving effects to the comparative advantages of the sector and regional popularity. We aim to clarify the causal relationship and propose more targeted policy recommendations. Fourth, the marine industry belongs to an emerging industry as it has just developed for a short time and has grown in tandem with the Internet, which will have a closer relationship with the Internet. In our study, the marine industry is separated from the other manufacturing industry. Given that the Internet significantly impacts OBM, researching OBM can yield distinct results.

2. Background information and some stylized facts

The marine economy is important for China to pursue high-quality economic development. This study selects the four-digit code of OBM from the *Industrial Classification and Codes for National Economic Activities*. As shown in Table 1, according to various industries' functions and division of labor in the national economy, OBM is specifically divided into five industries: marine mineral and seafood processing industry, marine shipbuilding industry, marine chemical industry, marine biomedical industry, and marine power industry.[4]

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[4] See Table 1 in the appendix for the four-digit code corresponding to a specific industry.

Stylized fact 1. *OBM is the marine economy's prospective leading industry and plays a significant role in promoting the overall development of the marine economy.*

Fig. 1 shows a development trend where OBM displays the characteristics of a prospective leading industry. First, following the global financial crisis in 2008, the growth rate of OBM fluctuated but increased significantly, which played an important role in promoting the local economy's recovery and improvement. Second, in recent years, the growth rate of the total output value of OBM shows a downward trend, but the structure is still continuously optimized. Traditional industries, such as marine mineral resources and seafood processing, continue to shrink, whereas strategic emerging industries, such as marine biomedical and marine power, are expanding. Overall, the scale of the marine economy is steadily increasing, the industrial structure is constantly being optimized, and product quality and competitiveness are constantly being strengthened.

We focus our study on OBM because its output may have a greater impact on the long-term development of China's marine economy. Fig. 2 indicates that the higher proportion of the OBM output in the marine economy, the higher the marine economy contributes to the local GDP in the coastal provinces of China.

The OBM plays a key role in the overall development of the marine economy. On the one hand, it provides major equipment and technical means for the production departments of the marine primary and tertiary industries, to fully improve the development and utilization capacity of various departments for marine resources. On the other hand, marine strategic emerging industries are concentrated in OBM, and their development will eventually improve the marine economy's overall development quality.

Stylized fact 2. *Compared with a land-based economy, OBM has the characteristics of liquidity, openness, capital, and technology-intensiveness.*

Compared with a land-based economy, the distinctive characteristics of the marine economy are as follows. First, the marine economy takes floating resources and vast marine space as the main development objects. It has liquidity characteristics because there are no significant barriers and marine production factors flow freely with ocean currents all over the world. Second, the characteristics of liquidity determine the openness of the marine economy, as the ocean connects resources and elements from various regions, countries, industries, and departments. Third, the marine economy is heavily reliant on capital and technology. The greater the investment and the higher the level of ocean-based technology, the greater the ability to develop marine resources. OBM can guide or attract foreign advanced manufacturing technology and high-end production equipment to enter the domestic market through close contact with the international market, improving the international competitiveness of local marine economic enterprises.

Stylized fact 3. *The Internet plays a more significant role in promoting the export of OBM compared with the land-based economy.*

Internet technology is a typical representative of high and new technology. Its popularization plays a vital role in promoting the export of enterprises in two aspects: One is to reduce enterprise information costs, and the other is to promote the sharing of innovative technologies among enterprises and form economies of scale. Compared with the land-based economy, the OBM is an economic activity that integrates high investment and high technology. Driven by the application of Internet technology, the application of a new generation of high-tech information technology has accelerated the development of marine resources. More importantly, the Internet also contributes to the transformation and upgrading of the OBM and enhances its competitiveness in the international market. Specifically, an electronic trading platform based on Internet technology can reduce enterprise information costs, realize technology sharing and economies of scale, and improve the international competitiveness of OBM firms' products. The Internet can be better applied to the production technology and product technology updating of OBM and improve the product structure of international trade of marine-related enterprises.

3. Data

3.1. Firm sample selection

Previous literature has mainly focused on the marine fishery, marine transportation industry, and other service sectors in China's marine economy. This research focuses on OBM. The reason for the emphasis on OBM is that its output may have a greater impact on the long-term development of China's marine economy. Fig. 2 indicates that the higher proportion of the output of OBM in the marine economy GDP contributes to the larger scale of marine economy GDP in the coastal provinces of China. Additionally, the data from the State Oceanic Administration show that the top three coastal provinces in the marine economy GDP, namely, Shandong, Jiangsu, and Guangdong, have a much larger scale of the output of OBM than other coastal provinces. Additionally, the proportions of the OBM output in the marine economy GDP have been increasing in these coastal provinces. Thus, the impact of the Internet on OBM, which is a dominant component of China's marine economy, must be examined.

The China Industrial Enterprise Database and the China Customs Enterprise Import and Export Information Database were merged using the methods used by Brandt et al. (2012). Then, two methods were used to select OBM firms. The first method identified OBM firms through their industry codes. According to the standard classification of marine industries in *The National Standards of the People's Republic of China*, OBM firms in the firm-level database at the four-digit-code level were selected. Although omitted observations due to selection under the classification method are unlikely, a few non-OBM firms may be included due to the over-identification problem of the identification standards. Firms' keywords were used as an alternative approach for a more precise search. For instance, the names

Table 2

Variable description and data source.

Variables	Variable description	Data sources
internet	The number of Internet users per 10,000 people in each province	China Internet Network Information Center (CINIC)
laborskill	The number of senior high school and above graduates per province-year to the total population	CEIC Database
traffic	The sum of railway kilometers and highway kilometers per province-year to the total population	CEIC Database
fai	Fixed capital investment per province-year to the total population	CEIC Database
intintens	The share of information and communications technology (ICT) capital services in total capital (the sum of ICT and non-ICT capital) services at the two-digit industry level for the United States in 1998	KLEMS Database
laborskilint	The share of transport expenses in total intermediate expenses at the two-digit industry level for China	China's National Bureau of Statistics (NBS)
traffint	The share of transport expenses in total intermediate expenses at the two-digit industry level for China	World Input-Output Database
capint	The ratio of total real capital to total employment at the two-digit industry level for China	Chinese Industrial Enterprise Database

of firms, main products, or other product names containing ocean-related keywords were identified as OBM firms. On the one hand, it may be impossible to list all of the keywords that reflect marine industry attributes; on the other hand, a considerable number of OBM firms may have names and products that do not reflect marine characteristics.[5] Thus, the advantage of this method is that all selected companies are OBM firms, although it may not cover all OBM firms in the database. For the analysis, this study mainly used the samples of OBM firms acquired using the first method, whereas the samples obtained using the second method were used for robustness testing to ensure that the regression results are stable and credible.

3.2. Province-level data

Four province-year variables were defined to reflect each province's comparative advantages in developing OBM: Internet penetration, skilled labor, transportation infrastructure, and fixed capital investment. Due to the heterogeneity of provincial characteristics and Internet usage privacy, the Internet penetration variable is denoted as the number of people using the Internet per 10,000 people in each province. Additionally, several options are available to measure Internet penetration, such as the length of fiber optic lines, which are the basis of the hardware facilities that enable the popularization of Internet applications and the length of fiber optic lines adjusted for population density in a province, computed by the length of provincial fiber lines per 10,000 people.

Other province-year variables indicating provincial comparative advantages include (i) the number of senior high school-and-above graduates per province-year, measuring skilled labor; (ii) railway and highway mileage per province-year, measured in kilometers of transport infrastructure; and (iii) fixed capital investment per province-year. Considering the heterogeneity of the size of each province, we adjusted the three aforementioned variables by the population per province-year: (i) the number of skilled labors per capita; (ii) the number of kilometers of railways and highways per capita; and (iii) the number of fixed capital investments per capita.

3.3. Sector-level data

To acquire the province-year-sector interaction variables, we must first obtain the industry-level time-invariant usage intensity. First, the share of information and communications technology (ICT) capital services in total capital (ICT and non-ICT capital) services at the two-digit industry level in the United States in 1998 was used to measure the intensity of Internet usage, alleviating the endogeneity concerns that may arise with a measure based on the Chinese Industry Enterprise Database. This measure is designated as the US share of ICT capital services. To further test the robustness of the regression results, this study uses the per capita length of fiber optic lines at a province-year level as an alternative indicator to measure Internet penetration. Meanwhile, as an alternative indicator of Internet usage intensity in the industry, the share of post and telecommunications expenses in the total intermediate costs at the two-digit industry level for China was used. This measure is designated as China's share of posts and telecommunications. The indicators for measuring the industry-level usage intensity variables in this study are for (i) skilled labor intensity, the share of college-educated workers at the two-digit industry level for China; (ii) transport intensity, the share of transport expenses in total intermediate expenses at the two-digit industry level for China; and (iii) capital intensity, the ratio of total real capital to total employment at the two-digit industry level for China.

Table 2 shows the data sources for the above core explanatory variables.

3.4. Firm-level data and descriptive statistics

The control variables involved in the regressions are mainly firm-year-level variables, including the number of employed laborers, workers' wages, and capital stock.

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[5] Keywords used for searching ocean-based firms included ocean, sea, deep-sea, marine, maritime, tide, seawater, seafood, oceangoing voyage, sea salt, seaweed, seafloor, oceangoing, ship, tramp, vessel, freighter, liner, offshore oil, offshore engineering, sea cucumber, sea-ear abalone, shrimp, lobster, and scallop.

Table 3
Descriptive statistics.

Variable	Observations	Mean	S.D.	Min	Max
Ocean-based manufacturing firms (Standard 1)	1951,239	0.12	0.32	0.00	1.00
Ocean-based manufacturing firms (Standard 2)	2115,642	0.01	0.09	0.00	1.00
US share of ICT capital	2113,975	0.03	0.05	0.00	0.17
China shares of post and telecommunications	2113,975	0.06	0.14	0.00	0.70
China transport intensity	2113,975	0.22	0.41	0.00	1.35
China skill intensity	2113,975	0.12	0.05	0.04	0.27
Log China capital intensity	2076,440	8.14	1.67	0.00	19.11
Log workers' wages	2028,046	7.03	1.36	0.00	15.79
Log exports	2115,636	2.37	4.17	0.00	19.01
Log number of employed labor	1444,574	4.66	1.14	0.00	13.25
Log capital stocks	2076,440	8.14	1.67	0.00	19.11
Province number of kilometers of railways and highways per capita	217	0.41	0.25	0.04	6.81
Province: Number of Internet users per capita	155	0.10	0.08	0.01	0.47
Province transport infrastructure	248	0.00	0.00	0.00	0.02
Log province fixed–capital investment	248	11.89	1.01	8.76	14.04
Log province number of skilled labor per capita	248	− 5.23	0.51	− 6.71	− 4.07

Table 3 provides the descriptive statistics of the main variables in the empirical model.

4. Empirical specification

4.1. Empirical strategy

To estimate the impact of the Internet on OBM, we used the empirical research method developed by Fernandes et al. (2019). Then, the following specification was considered for the empirical investigation:

$$Y_{jpst} = \beta_0 + \beta_1 internet_{pt} * intintens_s + \beta_2 laborskill_{pt} * laborskilint_s + \beta_3 traffic_{pt} * traffint_s + \beta_4 fai_{pt} * capint_s + \gamma_1 control_{jt} + I_j + I_{pt} + \varepsilon_{ipst}$$

where j stands for an ocean-based firm, p for province, s for industry, and t for year. The dependent variable Y_{jpst} denotes exports, which is used as a microlevel indicator of foreign trade of OBM firms in different industries in various provinces under the influence of Internet technology. ε_{ipst} is the error term clustered at an industry-province-year level. The core independent variable of the model is the interaction between a province-year measure of Internet penetration, $internet_{pt}$, and a province-industry measure of the intensity of Internet use, $intintens_s$. Consequently, β_1 is the coefficient of the key variable in this model, reflecting the growth effect of the Internet application on the dependent variable. First, the model controls for ocean-based firm-fixed effects and province-year fixed effects so that the coefficient estimation will be more accurate. I_j represents firm-fixed effect, which controls for unobserved missing variables at the firm level; I_{pt} denotes province-year fixed effects, controlling for unobserved missing variables that vary with province and year. Moreover, to consider additional province-industry level indicators of the comparative advantage that change over time, this study introduced the following three interactive terms: (i) the interaction between the number of skilled provincial laborers $laborskill_{pt}$ and industry-level skilled labor intensity $laborskilint_s$; (ii) the interaction between the indicator of provincial transportation facilities $traffic_{pt}$ and industry dependence on traffic $traffint_s$; and (iii) the interaction between the provincial fixed capital investment fai_{pt} and industrial fixed capital investment $capint_s$. Finally, several control variables at a firm level varying across years were introduced in the analysis to control for the effects of firm-level operating characteristics, including the number of employed laborers, workers' wages, and capital stock.

4.2. Endogenous problem

The main possible endogenous problem to consider is the interaction between the dependent and core independent variables. Whether OBM firms decide to use the Internet and the extent to which they use it depends on their exports and productivity. If the intensity of Chinese firms' ICT usage is taken as a variable, the endogeneity incurred will cause a bias in the estimation effect of Internet use. To account for this endogeneity, the proportion of ICT capital among total capital (the sum of ICT and non-ICT capital) at the two-digit industry level in the United States in 1998 is used as an alternative independent variable to calculate the intensity of Internet usage. Because it is exogenous to the production of Chinese firms, its use will mitigate the interference of endogeneity. To further test the robustness of the regression results, we used the length of the provincial optical fiber line per capita as an alternative indicator to measure Internet penetration. Considering that OBM firms' behavior may also affect the Internet usage of local residents, which will, in turn, lengthen the optical fiber line per capita, we chose the proportion of the post and telecommunications expenses among the total intermediate costs at the two-digit industry level for China as an alternative indicator to measure the intensity of Internet usage.

Table 4
Baseline regression results.

Dependent variable	(1) Log Exports	(2)	(3)	(4)
$internet_{pt} \times intintens_s$	17.608 * **	11.418 * **	10.862 * **	5.131 * *
	(3.150)	(3.034)	(3.156)	(2.046)
$laborskill_{pt} \times laborskilint_s$	0.187 *	0.848 * **	3.614 * *	0.556
	(0.108)	(0.109)	(1.417)	(0.458)
$traffic_{pt} \times traffint_s$	0.468 * **	0.425 * **	0.348	0.212
	(0.089)	(0.090)	(0.608)	(0.264)
$fai_{pt} \times capint_s$	0.022 * **	0.021 * **	0.105	0.024
	(0.005)	(0.005)	(0.072)	(0.019)
Log NO.employed labors		0.241 * **	0.241 * **	0.159 * **
		(0.026)	(0.026)	(0.023)
Log Workers' wages		0.538 * **	0.534 * **	0.109 * **
		(0.021)	(0.021)	(0.014)
Log Capital stock		0.349 * **	0.361 * **	0.045 * **
		(0.012)	(0.012)	(0.011)
Province-year fixed effects	NO	YES	YES	YES
Industry fixed effects	NO	NO	YES	–
Firm fixed effects	NO	NO	NO	YES
Number of observations	166,100	121,398	121,398	108,754
R-squared	0.078	0.200	0.205	0.878

Note: * , * *, and * ** indicate significance at the 10%, 5%, and 1% levels, respectively; numbers in parentheses are standard errors, clustered at province-sector-year.

Table 5
Robustness check.

Dependent variables	(1) Alternative	(2) Key words	(3) IP	(4) Forward
$internet_{pt} \times intintens_s$	5.371 * *	27.690 * *	0.050 * **	-1.334
	(2.223)	(11.373)	(0.012)	(2.921)
$laborskill_{pt} \times laborskilint_s$	-0.965 * *	1.095	-0.844 * *	-3.421 * **
	(0.423)	(0.910)	(0.416)	(0.708)
$traffic_{pt} \times traffint_s$	-0.261	-0.191 * **	-0.290	-1.402 * **
	(0.270)	(0.069)	(0.269)	(0.509)
$fai_{pt} \times capint_s$	-0.005	-0.082 *	0.001	-0.101 * **
	(0.017)	(0.046)	(0.016)	(0.026)
Control effects	YES	YES	YES	YES
Province-year fixed effects	YES	YES	YES	YES
Firm fixed effects	YES	YES	YES	YES
Number of observations	124,600	8286	127,265	41,978
R-squared	0.855	0.870	0.856	0.866
	(5)	(6)	(7)	(8)
Dependent variables	Lag	PR(export)	Identification code	Economic growth
$internet_{pt} \times intintens_s$	8.810 * *	0.515 * *	5.131 * *	6.064 * **
	(4.397)	(0.241)	(2.046)	(2.225)
$laborskill_{pt} \times laborskilint_s$	2.265 * *	0.084	0.556	1.404 *
	(0.889)	(0.060)	(0.458)	(0.792)
$traffic_{pt} \times traffint_s$	0.763 *	0.028	0.212	0.902 * *
	(0.391)	(0.032)	(0.264)	(0.397)
$fai_{pt} \times capint_s$	0.055 * **	0.003	0.024	0.026
	(0.021)	(0.002)	(0.019)	(0.027)
Control effects	YES	YES	YES	YES
Province-year fixed effects	YES	YES	YES	YES
Firm fixed effects	YES	YES	YES	YES
Number of observations	56,271	108,754	108,754	77,576
R-squared	0.919	0.848	0.878	0.901

Note: * , * *, and * ** indicate significance at the 10%, 5%, and 1% levels, respectively; numbers in parentheses are standard errors, clustered at province-sector-year.

5. Results

5.1. Baseline regression results

The estimation results in the analysis are based on the ocean-based firm database, and Columns (1)–(4) of Table 3 show the baseline regression results. First, Column (1) shows the reduced-form estimation result, indicating that the application of the Internet has a significant positive effect on the export value of OBM firms. In other words, higher Internet penetration can increase the probability of export participation for OBM firms. Second, when controlling for the province-year fixed effects and adding firm-level control variables in Column (2), the results still indicate that Internet technology application significantly boosts OBM firms' exports. This finding remains robust after adding industry-fixed effects (Column (3)) and firm-fixed effects (Column (4)). Ultimately, the results in Column (4) are chosen as the baseline regression conclusion. The results show that increasing the number of Internet users per capita in a province by one standard deviation increases OBM firms' exports by 5.13%.

In this section, the regression results further show that being technology driven is the most prominent characteristic of the outward-oriented marine economy. In this case, there are higher standards for the ocean-based market players and government departments in terms of technology and its application. First, the competent authorities of OBM firms should have higher administrative efficiency and market development-oriented insight. This means that authorities ought to adjust quickly according to market conditions and lead the market players in the right direction. As the marine economy has not yet reached a mature level of development, direct guidance for OBM firms must be strengthened. Nevertheless, because of inefficiency in government administration, export-oriented OBM firms face more obstacles than non-OBM firms. In comparison, ocean-based departments should accelerate the transformation of service-oriented government functions. Second, the outward-oriented OBM firms should have a longer-term vision to eliminate the traditional enterprise development factor-driven framework, and the Internet and other new generation information technologies must be prioritized for long-term development. Furthermore, to meet customers' needs with innovative technology, government policy orientation, and market development must be consistent over time, necessitating greater synergy between ocean-based departments and firms {{{Table 4}}}.

5.2. Robustness test

This part further tests the robustness of the benchmark regression results.

First, we replace the core explanatory variable (Alternative). To avoid potential endogeneity issues associated with using China's share of ICT capital and the firm-level database of China, we chose the US share of ICT capital as a surrogate index. To further mitigate the endogeneity problem, such as reverse causality (i.e., an export firm needs to contact a foreign business partner using the Internet may increase the Internet application of local residents), we test the validity of the findings by simultaneously using the province length of fiber optic lines per capita instead of the provincial number of Internet users per capita while replacing the US share of ICT capital with China's share of post and telecommunications. Column (1) of Table 5 displays the results of the corresponding regression analysis. A one standard deviation increase in the popularity of Internet applications leads to a 5.37% increase in the export value of OBM firms. This result is consistent with the baseline regression results in terms of both the magnitude and significance of the coefficients.

Second, we replace the sample (Key words). We use other OBM firms identified through keyword searching to determine whether the ocean-based firm indicators chosen are sufficiently robust. Column (2) of Table 5 displays the regression results, which show the promotion effect of the Internet on the export of OBM. Since keywords identify the OBM firms with distinctive maritime characteristics, their technology-driven characteristics are more obvious. The estimation shows that for every 1% increase in Internet penetration, the export value of OBM firms will increase by 27.69%.

Third, we used the Internet penetration indicator replacement. The total number of firm-level domain names was calculated separately at the industrial and provincial levels, and their interactive term was used as an alternative variable. Column (3) of Table 5 displays the regression results. The increase in Internet penetration has a significant positive effect on the exports of OBM firms, which is highly consistent with benchmark estimation research results.

Fourth, we conduct a placebo test (Forward). We replace the core explanatory variables with their forward terms to investigate whether future Internet infrastructure construction (2 years later) will affect the current period's export of OBM firms. Column (4) of Table 5 shows that future Internet application penetration has no significant impact on the export volume of OBM firms in the current period, and the coefficient is negative, confirming the causal relationship between Internet penetration and OBM firm export.

Fifth, we conduct a placebo test (Lag). Here, we replace the core explanatory variable with its lag term to investigate whether the construction of Internet infrastructure in the past 2 years (lagging behind the two phases) will affect the export of OBM firms in the current period. The regression results are shown in Column (5) of Table 5, which shows that the Internet infrastructure construction in the past 2 years still has a significant impact on the export of OBM firms in the current period, which further confirms the important role of the Internet in the export of OBM firms.

Sixth, we introduce the dummy variables (PR (export)). A dummy variable for whether the OBM firms export was used as the dependent variable instead of the logarithm of the export value. In Column (6) of Table 5, the regression result indicates that the Internet can significantly increase the probability of OBM firms participating in the export market, further proving the robustness of the previous conclusion.

Seventh, we conducted the accuracy test of identification code for ocean-based firms (Identification code). The marine industry identification code used in this paper was issued in 2003; thus, if the identification method is inaccurate enough, the non-OBM firms in

Table 6

Effect analysis of internet on firm export.

Dependent variables	(1) Export_ocean	(2) Export	(3) General	(4) Processing
$internet_{pt} \times intintens_s$	5.131 * *	5.147 * **	2.708 * **	1.554
	(2.046)	(0.725)	(0.879)	(3.539)
$laborskill_{pt} \times laborskilint_s$	0.556	0.543 * **	0.104	0.242
	(0.458)	(0.125)	(0.230)	(0.644)
$traffic_{pt} \times traffint_s$	0.212	-0.011	0.037	-0.121
	(0.264)	(0.014)	(0.145)	(0.382)
$fai_{pt} \times capint_s$	0.024	0.007 *	0.003	0.061 * *
	(0.019)	(0.004)	(0.011)	(0.030)
Control effects	YES	YES	YES	YES
Province-year fixed effects	YES	YES	YES	YES
Firm fixed effects	YES	YES	YES	YES
Number of observations	108,754	852,375	46,969	108,408
R-squared	0.878	0.879	0.900	0.785

Note: * , * *, and * ** indicate significance at the 10%, 5%, and 1% levels, respectively; numbers in parentheses are standard errors, clustered at province-sector-year.

Table 7

Effect analysis of internet on firm economic growth.

Dependent variables	(1) Eff_V-A_ocean	(2) Eff_V-A_noocean	(3) Eff_V-A_inter	(4) tfp_ocean	(5) tfp_noocean	(6) tfp_inter
$internet_{pt} \times intintens_s$	2.723 * **	0.301	-0.633	2.515 * **	-1.359 * **	-1.509 * **
	(0.879)	(0.285)	(2.647)	(0.533)	(0.183)	(0.188)
$inter\_ocean$			2.348 * **			1.702 * **
			(0.646)			(0.556)
$ocean$			0.015			-0.029 * *
			(0.014)			(0.015)
$laborskill_{pt} \times laborskilint_s$	0.115	0.052	-0.688	-1.032 * **	-0.908 * **	-0.921 * **
	(0.229)	(0.041)	(0.928)	(0.205)	(0.043)	(0.044)
$traffic_{pt} \times traffint_s$	0.040	-0.016 * **	-0.474	0.327 * *	0.003	0.005
	(0.145)	(0.005)	(0.531)	(0.129)	(0.005)	(0.005)
$fai_{pt} \times capint_s$	0.003	0.007 * **	-0.074	-0.001	-0.007 * **	-0.007 * **
	(0.011)	(0.001)	(0.050)	(0.010)	(0.001)	(0.002)
Control effects	YES	YES	YES	YES	YES	YES
Province-year fixed effects	YES	YES	YES	YES	YES	YES
Firm fixed effects	YES	YES	YES	YES	YES	YES
Number of observations	46,740	415,725	415,725	46,697	415,497	415,497
R-squared	0.830	0.819	0.819	0.869	0.872	0.872

Note: * , * *, and * ** indicate significance at the 10%, 5%, and 1% levels, respectively; numbers in parentheses are standard errors, clustered at province-sector-year.

the sample interval from 2000 to 2007 will be misidentified as potential problems of OBM firms. To eliminate the aforementioned problems in the identification method used in this paper, we remove the samples before 2003. The regression results are shown in Column (7) of Table 5, which shows no data exist in the regression samples before 2003. The new regression samples and results are completely consistent with those of benchmark estimation, demonstrating the accuracy of the identification method in this paper.

Eighth, we control the economic growth effect (Economic growth). In Column (8) of Table 5, the annual growth of provincial industrial export and the annual total factor productivity (TFP) growth of industries are controlled to eliminate the bias caused by potential differences in technology growth across industries. The results show that after controlling for the economic growth factors at the provincial and industry level, the coefficients are still significant, which once again demonstrates the significant role the Internet plays in promoting the export of OBM firms and the export-oriented development of the marine economy.

5.3. Comparative analysis of ocean-based and non-ocean-based manufacturing firms

Unlike the traditional land-based industry, the marine industry is a capital-intensive, technology-dependent industry that values openness and inclusion. Therefore, clear distinctions exist between OBM and non-OBM firms in terms of input selection, output selection, and production efficiency. Naturally, the impact of Internet construction on the development of OBM and non-OBM firms will differ significantly.

First, we compare the effect of Internet technology on the exports of OBM and non-OBM firms. The regression results in Columns (1) and (2) of Table 6 show that the use of Internet technology has a very obvious effect on the export growth of both OBM and non-OBM

Table 8

Mechanism and channel analysis.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variables	Labour	Labour_ocean	Invest	Invest_ocean	V-A	V-A _ocean
$internet_{pt} \times intintens_s$	0.757 * **	0.020	1.218 * *	0.438	0.259	2.338 * **
	(0.124)	(0.367)	(0.603)	(2.049)	(0.292)	(0.905)
$laborskill_{pt} \times laborskilint_s$	0.051 * *	-0.022	0.001	0.070	0.094	0.152
	(0.026)	(0.180)	(0.119)	(0.836)	(0.057)	(0.379)
$traffic_{pt} \times traffint_s$	-0.000	-0.081	-0.000	0.519	-0.019 * **	-0.138
	(0.003)	(0.076)	(0.014)	(0.407)	(0.006)	(0.180)
$fai_{pt} \times capint_s$	0.000	0.003	-0.002	0.038	0.008 * **	0.002
	(0.001)	(0.004)	(0.004)	(0.029)	(0.002)	(0.013)
Control effects	YES	YES	YES	YES	YES	YES
Province-year fixed effects	YES	YES	YES	YES	YES	YES
Firm fixed effects	YES	YES	YES	YES	YES	YES
Number of observations	71,548	666,304	477,873	52,083	347,350	40,557
R-squared	0.960	0.957	0.746	0.744	0.903	0.908

Note: * , * *, and * ** indicate significance at the 10%, 5%, and 1% levels, respectively; numbers in parentheses are standard errors, clustered at province-sector-year.

firms, and the regression coefficient and significance degree of the two are nearly the same, indicating that Internet technology can promote total export growth of both OBM and non-OBM firms. Although the difference in total export volume between OBM and non-OBM firms is not statistically significant, the differences in trade structure are significant. Columns (3) and (4) of Table 6 use the logarithm of ordinary trade volume and processing trade volume of OBM firms as the explanatory variables, respectively. The regression results show that Internet penetration has significantly improved ordinary trade for OBM firms but not processing trade. This result also suggests that Internet technology can improve the export structure of marine manufacturing firms, whereas the effect may not be obvious for nonmarine manufacturing firms.[6]

Second, this study returns to the analysis of the effect of the Internet on the economic growth of OBM and non-OBM firms. In Columns (1)–(3) of Table 7, we take the economic efficiency of value added of enterprises as the explanatory variable. First, in Columns (1) and (2), we separately investigate the role of Internet penetration on the improvement of the efficiency of value added of OBM and non-OBM firms. The regression results show that the greater the Internet penetration in the production process of OBM firms, the higher the economic efficiency of value-added OBM; however, the efficiency of value added of non-OBM firms will not be significantly affected by the Internet. Column (3) introduces the interaction term between enterprises and Internet penetration. The regression results show that the effect of the Internet on OBM firm exports is significantly higher than that of non-OBM firms. Moreover, we take firm productivity as the explanatory variable. The regression results in Columns (4) and (5) directly show that Internet penetration promotes the productivity of OBM firms while inhibiting the productivity of non-OBM ones. The interaction terms in Column (6) confirm the significant difference in productivity improvement between OBM and non-OBM firms by Internet technology.

Thus far, our empirical findings indicate that although Internet applications will boost export growth for both OBM and non-OBM firms, the effects of structural optimization and productivity improvement are significantly stronger on OBM firms than on non-OBM firms. Why is there such a significant difference? The test results on the mechanism and channels provide an answer to this question.

5.4. Mechanism analysis

How does Internet penetration promote the exports of OBM firms? This part explores the potential mechanism and channels of the firm behavior.

Enterprise production scale and efficiency are the key factors to measure whether enterprises can enter the export market. On the one hand, the Internet promotes the development of bilateral trade in the mode of trade liberalization. For example, the Internet has the potential to significantly reduce the cost of bilateral trade while also breaking down the original inherent barriers such as geography and information. On the other hand, Internet penetration will greatly change the business status of microenterprises: First, the use of the Internet will significantly improve the quality and scale of imported products from imported manufacturing enterprises, which will be more apparent in large-scale and efficient capital and technology-intensive enterprises. Second, the Internet is crucial in the horizontal upgrading of enterprise products, including higher quality and larger scale inputs and improving the enterprise's technological innovation ability to obtain a competitive advantage.

Internet penetration promotes the improvement of the overall business conditions of OBM firms by improving the business efficiency rather than the business scale, thus greatly increasing the export volume. The empirical results in Table 8 show that Internet penetration has heterogeneous export effects on OBM firms. In terms of the production scale of enterprises, Column (1) of Table 8 shows the regression of the number of laborers employed by non-OBM firms, and Column (2) shows the regression of the number of

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[6] Studies have shown that the Internet can promote the development of ordinary trade and processing trade by reducing the cost of international trade exchange and information (Anderson & Wincoop, 2004; Meliz, 2003).

Table 9
Industrial heterogeneity.

Dependent variables	(1) Log Export	(2)	(3)	(4)	(5)	(6)
	capital-intensive1	labour-intensive1	capital-intensive2	labour-intensive2	state-owned	no_state_owned
$internet_{pt} \times intintens_s$	4.521 * *	-57.148	6.027 * **	-8.850	0.966	4.839 * *
	(2.073)	(103.933)	(2.121)	(10.683)	(5.169)	(2.219)
$laborskill_{pt} \times laborskilint_s$	0.956 *	-6.648	0.622	2.152	-0.190	0.782
	(0.492)	(40.677)	(0.482)	(3.043)	(1.026)	(0.503)
$traffic_{pt} \times traffint_s$	0.336	-29.793	0.213	-0.844	-0.188	0.422
	(0.275)	(103.721)	(0.273)	(1.876)	(0.556)	(0.289)
$fai_{pt} \times capint_s$	0.029	92.994	0.035 * *	0.032	-0.009	0.028
	(0.019)	(95.584)	(0.015)	(0.062)	(0.035)	(0.021)
Control effects	YES	YES	YES	YES	YES	YES
Province-year fixed effects	YES	YES	YES	YES	YES	YES
Firm fixed effects	YES	YES	YES	YES	YES	YES
Number of observations	104,731	3626	98,415	6445	11,434	93,012
R-squared	0.879	0.877	0.881	0.878	0.901	0.879

Note: * , * *, and * ** indicate significance at the 10%, 5%, and 1% levels, respectively; numbers in parentheses are standard errors, clustered at province-sector-year.

laborers employed by OBM firms. The results show that Internet penetration will significantly encourage non-OBM firms to increase the number of laborers employed, but it will have no effect on OBM firms. The regression result of the investment scale of non-OBM firms is listed in Column (3) of Table 8 and that of the investment scale of OBM firms is listed in Column (4). The results show that Internet penetration will significantly promote non-OBM firms to increase their investment scale, but it is not significant in OBM firms. In terms of production efficiency of enterprises, Columns (5) and (6) of Table 8 take the logarithm of the per capita added value of OBM and non-OBM firms' unit labor workers as the explanatory variables. The regression results show that Internet technology significantly improves the value added of OBM firms while having a weak effect on the efficiency of non-OBM firms' added value.

Based on the regression results in Table 8, it is not difficult to find that OBM firms have still significantly improved their efficiency of value added without expanding the scale of labor force and additional investment. This conclusion indicates that the Internet promotes exports by improving the production efficiency of OBM firms rather than simply expanding their production scale. The development of the marine economy is quite different from that of the land-based economy; hence, the development of an export-oriented marine economy cannot replicate a land-based economy's extensive development model, nor can it achieve leapfrog development by simply expanding the scale of investment and production.

6. Heterogeneity analysis

6.1. Industrial export effects of the Internet

First, we reclassify the two-digit industry code of the manufacturing industry into two major industries: capital technology- and labor-intensive industry. The regression results are shown in Columns (1) and (2) of Table 9. The increasing popularity and application of the Internet have significantly boosted the export of capital-intensive OBM firms, whereas the export promotion effect of labor-intensive OBM firms is negligible. To validate the preceding conclusions, we define labor-intensive enterprises as those whose labor factor input to capital factor input ratio exceeds the average value and capital-intensive enterprises as vice versa. Columns (3) and (4) of Table 9 show the regression results for the two subsamples. Once again, it confirms that the application of the new round of technological revolution, such as the Internet, plays an important role in optimizing the export structure of the marine industry, which is mainly reflected in capital technology-intensive enterprises.

Second, to investigate whether Internet penetration has different effects on OBM firms with different ownership, we classify enterprises with more (*less*) than 25% of state-controlled enterprises as state-owned enterprises (*non-state-owned enterprises*). Columns (5) and (6) of Table 9 show the regression results. The Internet penetration does not significantly promote its export for OBM firms with state-controlled enterprises. By contrast, the export of non-state-controlled OBM firms is greatly promoted by the Internet. Compared with non-state-controlled firms, state-owned firms have higher capital adjustment costs and face greater distortion in capital price, which is one of the primary reasons for state-owned firms' TFP loss (Tang, 2021).

6.2. Regional export effect of the Internet

The export effect of Internet penetration on OBM firms in various regions reflects the degree of integration between the region's production and emerging technologies such as the Internet. To some extent, it also determines the level of development of the region's export-oriented marine economy and future marine economic development potential. Columns (1) and (2) of Table 10 regress OBM firms in the Bohai Rim and other regions, respectively. The regression results show that Internet penetration can positively promote the export of OBM firms in the Bohai Rim region, but the effect is not significant. Meanwhile, the Internet has a significant positive effect

Table 10
Regional Heterogeneity.

Dependent variables	(1) Log Export	(2)	(3)	(4)	(5)	(6)
	Bohai Rim	Other areas	Capital city	No capital city	L&M city	S city
$internet_{pt} \times intintens_s$	7.217	6.509 * *	8.746 *	5.239 *	5.409 * *	3.107
	(8.744)	(2.670)	(4.737)	(3.128)	(2.571)	(3.844)
$laborskill_{pt} \times laborskilint_s$	0.815	0.379	0.349	0.619	0.516	0.572
	(1.083)	(0.525)	(0.528)	(0.540)	(0.566)	(0.771)
$traffic_{pt} \times traffint_s$	0.179	0.135	0.175	0.232	0.491	-0.072
	(0.504)	(0.351)	(0.524)	(0.314)	(0.345)	(0.411)
$fai_{pt} \times capint_s$	0.097	0.002	0.028	0.019	0.038 * *	0.009
	(0.068)	(0.020)	(0.040)	(0.022)	(0.018)	(0.036)
Control effects	YES	YES	YES	YES	YES	YES
Province-year fixed effects	YES	YES	YES	YES	YES	YES
Firm fixed effects	YES	YES	YES	YES	YES	YES
Number of observations	28,159	78,734	8404	98,593	58,856	49,339
R-squared	0.863	0.882	0.881	0.879	0.880	0.875

Note: * , * * , and * ** indicate significance at the 10%, 5%, and 1% levels, respectively; numbers in parentheses are standard errors, clustered at province-sector-year.

on the export of OBM firms in other regions.

From 2000 to 2007, the Bohai Rim region became a region with the most rapid marine economic development in China by its unique geographical advantages and rich marine resources. However, the development of the marine industry in the Bohai Rim region still depends on the low-level development of marine resources and the production of primary products. By contrast, Internet penetration plays a significant role in promoting the export of OBM firms in other regions. In recent years, the scale and profitability of high-tech industries in the South, represented by the Yangtze and Pearl River Deltas, have shown a rapid growth trend. A new round of information technology represented by the Internet has become more popular and faster in the South. An increasing amount of capital flows to enterprises in the South, abundant capital, and advanced technology provide a fertile "thick soil" for developing marine industries.[7]

We also investigate whether the export effects of Internet penetration on OBM firms differ across city types. In Columns (3) and (4) of Table 10, we divide the sample into two subsamples based on whether the city where the OBM firms are located is the provincial capital city for regression. The regression results show that improving Internet penetration can significantly promote the export-oriented marine economic development of provincial and nonprovincial capital cities. For a 1% increase in Internet penetration, the export volume of OBM firms in provincial capital cities increases by 8.746%, whereas that of OBM firms in nonprovincial capital cities increases by 5.239%. These estimation results indicate that the Internet has a greater impact on the export promotion of OBM firms in provincial capital cities. One possible explanation is that provincial capital cities receive preferential policy dividends that can fully support the development of strategic marine emerging industries.

Furthermore, we divide China's prefecture-level cities into large- and medium-sized cities (first-tier, new first-tier, second-tier, and third-tier cities)[8] and small cities (fourth-tier and fifth-tier cities). From the regression results in Columns (5) and (6) of Table 10, the improvement of Internet penetration can significantly promote the participation of OBM firms in large- and medium-sized cities in international trading activities. However, it does not significantly promote the export of OBM firms in small cities. Compared with small cities with relatively backward economic development, large- and medium-sized cities have improved infrastructure construction and more convenient information exchange, which are more attractive to large investors and enterprises. As a typical capital-intensive high-end manufacturing industry, OBM firms will be more inclined to settle in large- and medium-sized cities.

7. Conclusions

With China's opening to the international market, the country's outward-oriented marine economy is playing an important role in its economic growth. This study investigates the impact of Internet penetration on exports of OBM, thereby highlighting a novel channel for the promotion of the marine economy. This study provides the following conclusions.

First, the Internet rollout boosted exports in OBM firms, showing a significant technology-driven effect. The result shows that an increase of one standard deviation in the number of Internet users per capita in a province leads to a 5.13% increase in the exports of OBM firms. The salient size of the coefficient reveals that a prominent characteristic of an outward-oriented marine economy is being technology driven, and it is especially important to seize the opportunity of the new generation of information technology revolution to achieve sustainable development.

Second, there exists a significant heterogeneity in the effects of Internet penetration on the export development and economic growth of OBM and non-OBM firms. Internet penetration improves the export structure of OBM firms, but the effect is less obvious for

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[7] See the Appendix for corresponding data support and analysis.
[8] Ranking list of 2021 urban commercial charms released by China first finance and Economics.

Table A1

Ocean-based manufacturing and the four-digit code.

Category	The four-digit code
Marine mineral and seafood processing industry	1361, 1362, 1363, 1364, 1369, 1452, 0710, 0790, 0810, 1493, 3697, 0912, 0911, 0913, 0914, 0917, 0919, 0921, 0922, 0929, 0933, 1020, 1030, 1093, 1099, 1019, 1100, 0610, 0620, 0690, 0890, 3631, 3632, 1011, 1012, 1013, 4690, 3611, 3632, 3676, 3675, 3679, 4124, 3612, 1320, 1432, 1439, 1462, 1469, 2511, 2512, 2644
Marine shipbuilding industry	3755, 3759, 3431, 3791, 3530, 3991, 3519, 4119, 3543, 3544, 3751, 3752, 3753, 3433, 1755, 3440, 1751, 3511, 3512, 3513, 3551, 3552, 3754, 3541, 3571, 4014, 4020, 4123, 4130
Marine chemical industry	3572, 4111, 4114, 3541, 3579, 2611, 2612, 2613, 2614, 2619, 3573, 3432, 3499, 2641, 4121, 3691, 2661, 2662, 2665, 2210, 2671, 2672, 2673, 2621, 2623, 2629, 2624, 2631
Marine biomedical industry	3644, 2710, 2760, 2720, 2730, 2740, 1491, 2750, 2666
Marine power industry	4419, 4411, 4413, 3931, 3932

Fig. A1. Comparison of marine strategic emerging industrial structure in four regions of China. *Note: We take the export volume of the Bohai Economic Rim as the benchmark.*

non-OBM enterprises. Additionally, the Internet significantly promotes the productivity and efficiency of value added of OBM firms, playing a key role in increasing profit and realizing upgrading.

Third, our potential mechanism analysis shows that the export promotion induced by Internet penetration is due to a productivity effect rather than a scale effect. Unlike the traditional studies on land-based firms, OBM firms are more likely to develop by improving TFP rather than increasing investment when faced with limited marine resources and increased environmental constraints.

Fourth, the Internet has cross-regional and cross-industry heterogeneous effects on the exports of OBM firms. In terms of the industrial export effect of the Internet, Internet penetration is conducive to the export of capital and technology-intensive marine industries but not to exporting labor-intensive marine industries. In terms of OBM firms, the export of non-state-controlled OBM firms has been significantly promoted by the Internet, and the state's capital does not play a major role in the development of the marine economy. Furthermore, although increased Internet penetration can significantly increase the participation of OBM firms in international trade in large- and medium-sized cities, it does not significantly increase export in small cities. In recent years, the southern regions represented by the Yangtze River Delta and the Pearl River Delta has shown a rapid growth trend in the scale and profitability of high-tech industries, whereas the export promotion effect of the Internet on OBM firms is not significant in the Bohai Rim region, a traditional marine economic zone with low total investment in marine high-tech industries. In the future, local governments should actively introduce advanced technology and management experience and strengthen cross-industry and cross-regional orderly competition.

Funding

Declaration of interest

None

Data Availability

Data will be made available on request.

Appendix

(1) Definition of ocean-based manufacturing industries and the four-digit code {Table A1}

(2) Comparison of marine strategic emerging industrial structure in four regions

We divide other regions into Yangtze River Delta, the Four Southern Coastal Provinces, and Inland Regions; the radar charts are drawn based on the total output and total export of marine mineral and seafood processing industry (MMSPI), marine shipbuilding industry (MSI), marine chemical industry (MCI), marine biomedical industry (MBI) and marine power industry (MPI) around the Bohai Rim (as shown in Fig. A1). As can be seen from Fig. A1., in 2000, the total export volume of only marine mineral and seafood processing industry, marine chemical industry, and marine biomedical industry in Yangtze River Delta exceeded that in Bohai Economic Rim, and the total export volume of the five marine strategic emerging industries in The Four Southern Coastal Provinces and Inland Regions was almost less than that in Bohai Economic Rim. However, in 2007, Yangtze River Delta produced more marine strategic emerging industries. The development of the industry has made a great leap. The total export volume of the five industries has surpassed Bohai Economic Rim, and the Four Southern Coastal Provinces and Inland Regions also show an obvious expansion trend.

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