Driving Export Sophistication Through Industry Integration: Evidence from Chinese Manufacturing Firms

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Abstract. Against the backdrop of increasingly deep global industrial division of labor, improving the technological complexity of export products has become crucial for the high-quality development of China's manufacturing industry. With the rise of the modern service industry, the integration of manufacturing and services has increasingly emerged as an important pathway for enterprise transformation and upgrading. Based on data from A-share listed manufacturing companies in China from 2007 to 2019, this paper investigates the impact and mechanisms of industry integration on the technological complexity of firms' exports. The study finds that industry integration significantly enhances the technological complexity of firms' export products. This effect remains robust after a series of tests, including excluding municipalities from the sample, propensity score matching, adjusting the sample period, and using instrumental variable methods. Further heterogeneity analysis shows that firms in the eastern region and non-state-owned enterprises benefit more significantly from industry integration, particularly in terms of improving technological innovation and resource allocation efficiency. Mechanism analysis indicates that industry integration improves export technological complexity through three main channels: technological innovation capability, the proportion of foreign direct investment (FDI), and resource allocation efficiency. Based on these findings, this paper suggests that policies should strengthen support for the central and western regions, optimize foreign investment attraction strategies, and promote enterprise service-oriented transformation to enhance technological innovation capabilities and resource allocation efficiency.

Keywords: Integration of Manufacturing and Services, Export Technological Complexity of Enterprises, Technological Innovation, Resource Allocation Efficiency.

1. Introduction

Amid the deepening and restructuring of global industrial division of labor, enhancing the technological content and added value of export products has become a core strategic choice for countries striving to "move up" in the global value chain. Particularly for China, the 14th Five-Year Plan and the 2035 Vision Goals have placed the construction of a modern industrial system and the promotion of high-quality development at the forefront. Traditional export models based on quantity and cost advantages are increasingly inadequate for adapting to the complex international economic environment. Therefore, improving the technological complexity of exports and realizing the transformation from a "large manufacturing country" to a "strong manufacturing nation" have become strategic imperatives. Meanwhile, with the rapid rise of the modern service industry and the widespread penetration of digital technologies, the boundary between manufacturing and services has become increasingly blurred. The integration of manufacturing and services has emerged as a key pathway for upgrading and transforming Chinese manufacturing.

In recent years, a series of national policies have emphasized the need to promote the deep integration of manufacturing and services (hereinafter referred to as "industry integration"). Policies such as the Special Action Guide for Service-Oriented Manufacturing, the 14th Five-Year Plan for High-Quality Development of Manufacturing, and the Guidelines on Promoting the High-Quality Development of Manufacturing Services issued by the Ministry of Industry and Information Technology have explicitly called for the acceleration of service-oriented manufacturing and the extension of the manufacturing process towards the high end of the value chain. The embedding of service elements not only changes enterprises' production organization methods but also reshapes their product structures, customer relationships, and market response mechanisms. Against this backdrop, studying whether and how industry integration affects the technological complexity of firms' export products is not only aligned with national strategic objectives but also holds significant theoretical and practical importance.

Export technological complexity is a key indicator for measuring a country's or a firm's position within the international division of labor. The Export Complexity (EXPY) framework proposed by Hausmann, Hwang, and Rodrik (2007) has been widely adopted to evaluate the technological content and knowledge intensity embedded in product structures. In the context of China, relevant studies have shown that enhancing export technological complexity contributes to greater resilience against external shocks, longer export life cycles, and higher economic growth potential (Sheng Bin & Mao Qilin, 2017). However, current research on factors influencing export complexity largely focuses on external factors such as R&D investment, industrial policy, and foreign direct investment (FDI), while relatively few studies explore how internal structural changes within firms, particularly service-oriented transformation and industry integration, shape export structures. This gap provides an opportunity for this paper to make a marginal contribution.

There is already abundant literature on the pathways, influencing factors, and performance outcomes of industry integration. Li et al. (2023) noted that the synergy between manufacturing and services can enhance organizational flexibility through knowledge complementarity and process integration. Zhang Xing et al. (2022), using a coupling coordination model, measured regional levels of industry integration and found that it had a significantly positive effect on regional innovation capabilities. However, existing studies mainly focus on macro-level index construction and institutional evaluations, with relatively little attention paid to firm-level, especially export-oriented, analyses. Similarly, studies on export complexity often emphasize macroeconomic structures, technology introduction, or trade policy (Hausmann et al., 2007; Zheng Zhanpeng et al., 2017), but insufficiently address how organizational changes within firms, such as service-oriented transformation, influence export complexity. This paper, by focusing on industry integration, aims to bridge this research gap.

On the theoretical side, this study, based on organizational learning theory and the theory of industrial value chain evolution, proposes that industry integration influences firms' export technological complexity through three core mechanisms. First, the embedding of service elements into manufacturing can improve production efficiency, accelerate technological innovation, and thus promote export technological complexity. Wang Siyu and Zheng Lekai (2019) pointed out that service embedding helps manufacturing enterprises better meet customers' personalized needs, thereby enhancing R&D capabilities and product differentiation. Second, foreign direct investment introduces advanced management experience and generates technology spillover effects, promoting technological progress and increased product complexity among local firms. Regions with higher levels of industry integration are more attractive to high-end FDI. The technological knowledge and international standards brought by foreign-invested enterprises help local firms enhance the technological content of their products and their export level (Cui et al., 2024). Third, organizational restructuring and process reengineering help optimize resource allocation, improve production efficiency, and provide a stable foundation for the production of high-tech products (Sun et al., 2025). Such optimization across the entire industrial chain lays a foundation for enterprises' sustainable development and the improvement of their international competitiveness.

On the empirical side, this study uses panel data of A-share listed manufacturing firms in China from 2011 to 2016 to analyze the impact of industry integration on export complexity and its underlying mechanisms. Baseline regression results show that higher levels of industry integration significantly improve the technological complexity of firms' exports, and this positive relationship remains robust after conducting various robustness checks, including excluding municipalities from the sample, employing propensity score matching (PSM), adjusting the sample period, and using instrumental variable (IV) methods. Mechanism analysis shows that firms benefit significantly from improved R&D investment, enhanced profitability, and absorption of spillover effects from foreign investment in optimizing their product structures. Among these, technological innovation capability plays the most stable mediating role, indicating that the transformation of manufacturing processes through service embedding primarily drives export upgrading by stimulating firms' technological potential. Moreover, heterogeneity analysis shows that this positive impact is more pronounced in non-state-owned enterprises, firms located in eastern regions, and high-tech industries, suggesting that resource endowments and institutional environments significantly moderate the effectiveness of industry integration.

This paper makes three primary contributions: first, it systematically evaluates the impact of industry integration on export complexity at the micro (firm) level, thus addressing a gap in existing literature; second, by introducing mechanism variables such as technological innovation, foreign direct investment, and resource allocation efficiency, it reveals the internal logic by which integration promotes export structure upgrading; third, it identifies regional and firm-specific heterogeneities, providing theoretical support for future differentiated policy formulation.

The structure of this paper is organized as follows: Section 2 introduces the relevant institutional background and theoretical framework; Section 3 details the research design, including sample selection, variable definitions, and model setting; Section 4 presents and analyzes the main empirical results; Section 5 explores the potential mechanisms; Section 6 conducts heterogeneity analysis; and Section 7 concludes the paper with policy recommendations and directions for future research.

2. Literature Review

2.1. Integration of Manufacturing and Services

In recent years, with the advancement of a new round of technological revolution and industrial transformation, the boundary between manufacturing and services has gradually blurred. Integration of manufacturing and services has become an important strategic pathway for global manufacturing industries to achieve transformation and upgrading. Integration refers to the deep embedding of service elements into multiple aspects such as product development, production processes, organizational management, and business models (Liu et al., 2023). This process not only reshapes the value chain structure of traditional manufacturing but also significantly enhances enterprises' innovation capabilities and market responsiveness. By embedding service elements such as design, logistics, customer support, and financial services, manufacturing firms are gradually transforming from "product providers" into "comprehensive solution providers," thereby creating more value and efficiency improvement opportunities. This transformation process has also become a major direction encouraged by industrial policies in recent years (Wang Wei et al., 2024).

At the research level, early literature on integration mainly focused on its macro-level economic benefits and the evolution of industrial structures. Cainelli et al. (2015) emphasized that digital transformation improves the production efficiency of manufacturing and enhances its competitiveness in international markets. Huseyni and Cakmak (2020) further pointed out that digitalization not only raises export complexity but also promotes deep synergy between manufacturing and services through platformization and service integration, bringing new competitive advantages to enterprises. As research deepened, academic attention gradually shifted to the micro-enterprise level. Kohtamäki et al. (2020) and others proposed that integration has a profound impact on firms' value creation models, organizational transformation, and performance, especially through the linkage between servitization strategies and innovation capabilities.

From the perspective of technological innovation, integration provides enterprises with new pathways for knowledge integration and capability reconstruction. Jiao Ping et al. (2023) found that the embedding of service functions not only enhances collaborative innovation capabilities among enterprises but also effectively alleviates financing constraints faced by SMEs during technological upgrading. In the context of widespread application of information and communication technologies (ICT), Wang et al. (2022) pointed out that servitization strategies combined with technological collaboration significantly enhance product technological complexity, thereby positively impacting firms' export structures. This effect is particularly prominent in regions with a higher level of digital economy development (Li Junjiu et al., 2024). Branstetter and Lardy (2018), from the perspective of organizational culture, emphasized that in institutional environments tolerant of failure, firms are more willing to engage in high-technology, high-difficulty export attempts, especially when supported by digital services that enable them to access high value-added markets more effectively and enhance their international competitiveness.

Research on international market expansion also shows that integration plays a significant role in promoting firms' outward-oriented development. Based on regional coordination measurements, Zhang Xing et al. (2022) found that firms with a higher degree of integration tend to exhibit stronger market customization responsiveness and greater brand premium capabilities. Silva et al. (2012) demonstrated that "servitization innovation," achieved through the integration of services into manufacturing, supports enterprises in entering high-value export markets. Khan et al. (2024) supplemented from the perspective of green transformation, arguing that service embedding helps improve energy efficiency and optimize industrial structures, thereby indirectly enhancing firms' international competitiveness.

2.2. Export Technological Complexity

Research on export technological complexity also provides a structural perspective for understanding enterprise competitiveness. Hausmann et al. (2007) first introduced the concept of Export Sophistication to measure the technological content and added value of export products. Compared with traditional indicators of export volume, this measure places greater emphasis on the quality of the export structure. Sheng Bin and Mao Qilin (2017) localized this indicator to the Chinese context, highlighting its close relationship with innovation and market positioning. Dang Lin et al. (2021) argued that digital transformation significantly enhances the complexity of intermediate goods exports. Hu Ying et al. (2024) suggested that improvements in digital infrastructure optimize resource matching efficiency and enhance export quality. Bao Xiaozhong (2024) found that export complexity exhibits nonlinear characteristics, necessitating the rational allocation of technology and capital. Zhao Chunming et al. (2025) demonstrated that investments in smart manufacturing and digital technologies improve the technological sophistication of exports.

The institutional environment and organizational culture also play crucial roles in enhancing export technological complexity. Human capital accumulation forms the foundation for promoting complexity growth (Sheng Bin et al., 2017), while institutional quality affects the capacity to absorb technological spillovers under open conditions (Zheng Zhanpeng et al., 2017). Dai Kuizao (2018), from the perspective of "soft mechanisms," pointed out that a favorable organizational culture and robust intellectual property protection significantly boost enterprises' willingness to engage in high-technology exports.

In recent years, green transformation and digitalization have become new driving forces for export technological complexity. Su Chenchen et al. (2025), using "green factories" as a quasi-natural experiment, found that policy incentives and green reputation mechanisms jointly improved firms’ technological complexity. Liu Jingling et al. (2024), based on data from cross-border e-commerce pilot zones, confirmed the positive role of digital platforms in promoting high-complexity exports. Song Guohao et al. (2024) suggested that improvements in public services promote technological innovation and export market diversification, thereby enhancing export quality. Moreover, the institutional environment and policy tools have also become important influencing factors. Dong Peng (2024) and Niu Hua et al. (2024) emphasized that the combination of strong property rights protection and high levels of digital transformation forms the institutional basis for enhancing export complexity. Pan Shuang et al. (2024) and Li Jiamei et al. (2024) further pointed out that there exists a nonlinear interaction between government subsidies and digital economy development, and this combination mechanism significantly boosts export complexity.

In summary, existing studies have made significant progress in exploring the drivers and effects of industry integration and the determinants of export complexity, and have preliminarily revealed the potential pathways through which servitization transformation influences firms' export quality. However, most studies are based on provincial or city-level data, lacking firm-level empirical analyses that capture enterprise heterogeneity. Moreover, the majority of research focuses on the impacts of integration on innovation and performance indicators, without sufficiently exploring its influence on export product structures and technological complexity. Therefore, based on data from A-share listed companies in China from 2007 to 2019, this paper constructs firm-level indices for industry integration and export technological complexity to systematically examine the impact of industry integration on firms' export technological complexity and its transmission mechanisms. This study reveals how industry integration improves the quality of firms' export product structures through these mechanisms. The research not only fills the gap in micro-level empirical evidence between industry integration and export complexity but also provides theoretical support and practical insights for enterprises seeking to enhance their international competitiveness under the context of high-quality opening-up.

3. Research Hypotheses and Empirical Design

3.1. Research Hypotheses

With the intensification of global manufacturing competition and the growing international demand for high value-added products, enhancing the technological complexity of export products has become a key pathway for Chinese manufacturing enterprises to achieve high-quality development. Against this backdrop, the deep integration of manufacturing and services, as an important approach to reshaping organizational models, optimizing resource allocation, and enhancing innovation capabilities, has attracted increasing attention for its role in shaping export product structures. The introduction of service elements not only expands firms' value creation boundaries but also leads to high synergy across product design, customer feedback, and after-sales service, thereby providing a practical foundation for functional and technological upgrades in export products (Parida et al., 2015). Integration of manufacturing and services may thus serve as an important driving force for improving the technological complexity of enterprises’ exports.

Theoretically, the deep integration of services with manufacturing can enhance firms’ responsiveness to market demand changes and improve their ability to provide customized, technology-intensive products, thereby optimizing the technological structure of their exports. Service-oriented manufacturing facilitates firms' accumulation of technological knowledge, organizational learning, and resource integration efficiency, making it easier for enterprises to break away from low-end path dependence and achieve higher value-added positions within the global value chain (Wang et al., 2022; Sheng Bin & Mao Qilin, 2017). Therefore, the following main hypothesis is proposed:

H1: Industry integration significantly promotes the technological complexity of firms' export products.

Based on existing theories and literature, this paper further proposes three potential mechanism paths: technological innovation capability, FDI absorption capability, and resource allocation efficiency. First, technological innovation capability is an important transmission mechanism through which industry integration influences export technological complexity. By introducing service functions, enterprises place greater emphasis on customer feedback, product differentiation, and customized solutions, thereby accelerating R&D investment and technological upgrading (Zhang Xing et al., 2022). Moreover, this integration process fosters cross-departmental collaboration and knowledge sharing within enterprises, enhancing organizational learning and technological accumulation (Wang et al., 2022). For example, Cainelli et al. (2015) found in a study of Italian firms that service embedding significantly improves environmental innovation capabilities and process complexity, providing momentum for technological upgrading of export products. Therefore, the embedding of service elements in production processes not only stimulates technological improvement and product innovation demands but also provides organizational support for firms to develop systematic innovation capabilities, making it more likely for them to transform R&D achievements into technology-intensive export products. Based on this, the following hypothesis is proposed:

H1-a: Industry integration enhances firms' export technological complexity by improving their technological innovation capability.

Second, FDI absorption capability serves as a key channel through which knowledge spillovers and global resource integration occur, and it is an important pathway through which industry integration influences export product structures. Enterprises with a higher degree of servitization demonstrate stronger performance in organizational standardization and external compatibility, making them more attractive to high-quality foreign investment projects and better able to leverage foreign capital's advantages in technology, management, and quality control (Liu Jiamin, Li Zheng, & Guo Xiao, 2024). Existing research shows that FDI not only brings capital investment but, more importantly, provides opportunities for technology transfer and organizational learning, helping local enterprises break away from original technological paths and evolve toward high-complexity product exports (Zhou, Liu, & Buck, 2022). Enterprises with a high level of integration are more internationally compatible in terms of organizational models, management systems, and standardization, making them more attractive to high-quality foreign investors. The advanced technologies, management experience, and international certification systems brought by foreign investment not only enhance firms' operational capabilities but also guide the upgrading of their export products to higher technological levels through a "learning effect." Based on this, the following hypothesis is proposed:

H1-b: Industry integration enhances firms' FDI absorption capability, thereby optimizing the technological structure of their export products.

Third, resource allocation efficiency is reflected in the optimization and efficient allocation of production factors during the integration of manufacturing and services. A servitization strategy requires enterprises to restructure their business processes and organizational architectures, achieving coordinated operation of capital, technology, and labor, thus enhancing overall production efficiency (Bao Xiaozhong, 2024). Following the advancement of digital economy-driven industry integration, firms show significant improvements in capital utilization rates and labor productivity. Efficient resource allocation reduces the marginal costs and uncertainties associated with the export of high-tech products, enabling firms to better meet the demands and standards of complex markets (Wu, 2023). Therefore, the servitization transformation encourages enterprises to optimize their business processes and restructure their organizational frameworks, thereby improving output efficiency per unit of input. Efficient resource allocation ensures the stable export of high-complexity products, enabling firms to undertake high-standard, high-technology export tasks (Scerri & Agarwal, 2018). Based on this, the following hypothesis is proposed:

H1-c: Industry integration improves firms' resource allocation efficiency, thereby facilitating the technological complexity enhancement of their export products.

3.2. Empirical Design

(1) Model Specification

To verify the impact of industry integration on firms' export complexity, following the approach of Sheng Bin and Mao Qilin (2017), the following regression model is established:

$$esi_{i,t} = \beta_0 + \beta_1 Fusion_{i,t} + \beta Control_{i,t} + \varphi_i + \mu_t + \varepsilon_{i,t} \tag{1}$$

where $\mathrm{esi}_{\mathrm{it}}$ represents the export complexity of firm i in year *t*, and $Fusion_{it}$ denotes the level of industry integration for firm i in year *t*. $Control_{i,t}$ is a set of control variables; φ_i and μ_t represent firm fixed effects and year fixed effects, respectively.$\varepsilon_{i,t}$ is the random error term. The core coefficient of interest is β_1.If β_1 is significantly positive, it indicates that industry integration promotes firms' export complexity.

(2) Measurement of Key Variables

1. Dependent Variable: Export Technological Complexity. The measurement of firms' export technological complexity follows the methodology of Sheng Bin and Mao Qilin (2017), with specific procedures as follows:

First, based on Balassa (1965), the revealed comparative advantage (RCA) index of country c in product *k* at the HS6-digit code level is calculated. Let x_{ck} denote the export value of country c for product *k*, and x_{ck} denote the total export value of country *c*. The RCA formula is:

$$RCA_{ck} = \frac{(x_{ck}/X_c)}{\sum_c (x_{ck}/X_c)} \tag{2}$$

Next, the RCA index for each country-product pair is multiplied by the country's per capita GDP ($\boldsymbol{rGDP_c}$) to obtain the product-level export sophistication:

$$PRODY_k = \sum_c RCA_{ck} * rGDP_c \tag{3}$$

Finally, the export sophistication at the firm level is constructed. Let x_{ik}/X_i represent the proportion of firm *i*'s export value of product *k* in its total exports. The firm-level export complexity is calculated as:

$$esi_i = \sum_k \frac{x_{ik}}{X_i} PRODY_k \tag{4}$$

This index comprehensively measures the technological sophistication and value-added level of a firm's export products.

2. Core Independent Variable: Industry Integration Level. Following the methodologies of Li Lin and Zhao Heng (2021), and Jiao Ping and Tian Renxiu (2023), this paper measures the level of industry integration (Fusion) using the entropy method. The entropy method objectively assigns weights based on the dispersion degree of indicators, avoiding subjective bias and being suitable for comprehensive measurements involving multi-dimensional indicators.

Adhering to the principles of scientificity, comprehensiveness, and data availability, an evaluation system is constructed from four dimensions: industrial scale, industrial structure, production efficiency, and development potential, as shown in Table 1.

Table 1. Evaluation System for Industry Integration Level

Primary Indicator	Secondary Indicator	Description
Industrial Scale	Output value of advanced manufacturing (billion RMB)	Reflects the economic scale of advanced manufacturing.
	Output value of modern services (billion RMB)	Reflects the economic scale of modern services.
Industrial Structure	Share of employment in advanced manufacturing (%)	Ratio of employees in advanced manufacturing to the total employment of both sectors, reflecting labor distribution.
	Share of employment in modern services (%)	Ratio of employees in modern services to the total employment of both sectors.
Production Efficiency	Labor productivity of advanced manufacturing (RMB/person)	Output value divided by the number of employees in advanced manufacturing.
	Labor productivity of modern services (RMB/person)	Output value divided by the number of employees in modern services.
Development Potential	Growth rate of advanced manufacturing output value (%)	(Current year - Previous year)/Previous year ×100%, reflecting the growth trend.
	Growth rate of modern services output value (%)	(Current year - Previous year)/Previous year ×100%, reflecting the growth trend.

To control for other factors that may influence export complexity, the model includes a set of control variables: firm size (*Size*), leverage ratio (*Lev*), return on assets (*ROA*), return on equity (*ROE*), asset turnover (*ATO*), cash flow ratio (*Cashflow*), years since listing (*ListAge*), firm age (*FirmAge*), and auditor type (*Big4*). Additionally, year fixed effects are controlled to account for macroeconomic changes, and industry fixed effects are controlled to mitigate sector-specific influences. To address potential cross-sectional correlation issues, all regressions employ firm-level clustered standard errors. Detailed variable definitions are shown in Table 2.

Table 2. Variable Definitions and Constructions

Variable Symbol	Variable Name	Definition and Description
esi	Export complexity	An indicator that measures the technological sophistication or value-added level of a firm's exports based on product structure and technology data.
Fusion	Industry integration level	An index reflecting the degree of integration between industries, constructed based on industry linkage and resource integration dimensions.
Size	Firm size	Measured by total assets at year-end.
Lev	Leverage ratio	Ratio of total liabilities to total assets.
ROA	Return on assets	Net profit divided by average total assets.
ROE	Return on equity	Net profit divided by net assets.
ATO	Asset turnover	Operating revenue divided by average total assets.
Cashflow	Cash flow ratio	Cash flows from operating activities divided by operating revenue.
ListAge	Years since listing	Natural logarithm of 1 plus the number of years since listing.
FirmAge	Firm age	Natural logarithm of 1 plus the number of years since establishment.
Big4	Auditor type	Dummy variable: 1 if audited by an international Big Four accounting firm, 0 otherwise.

3.3. Data Source

This study uses A-share listed companies in China from 2007 to 2019 as the research sample. Based on data from the China Stock Market & Accounting Research (CSMAR) database and matched data from customs and industrial enterprise databases, a panel dataset is constructed, containing variables such as export technological complexity (*esi*), industry integration level (*Fusion*), and a set of control variables.

The sample selection process is as follows: firms under ST or *ST status and those in the financial industry are excluded; firms with missing values in key variables are also excluded. The final sample consists of 10,864 valid observations. To address potential outliers, all continuous variables are winsorized at the 1st and 99th percentiles.

3.4. Descriptive Statistics

Table 3 presents the descriptive statistics of the main variables. The dependent variable, export technological complexity (*esi*), has a mean of 609.8 and a standard deviation of 1,051, with values ranging from 0 to 5,166, indicating substantial variation in export complexity across firms.The core explanatory variable, industry integration level (*Fusion*), has a mean of 0.262 and a standard deviation of 0.183, ranging from 0.0423 to 0.841, suggesting heterogeneous degrees of industry integration among firms.Control variables such as firm size (*Size*) and leverage ratio (*Lev*) also exhibit varying degrees of dispersion.

Table 3. Descriptive Statistics of Main Variables

Variable Type	Variable	Observations	Mean	Std. Dev.	Min	Max
Dependent Variable	*esi*	10,864	609.8	1,051	0	5,166
Core Explanatory Variable	*Fusion*	10,864	0.262	0.183	0.042	0.841
Control Variables	*Size*	10,864	22.080	1.284	19.870	25.830
	Lev	10,864	0.418	0.215	0.0503	0.873
	ROA	10,864	0.047	0.051	-0.111	0.200
	ROE	10,864	0.078	0.093	-0.330	0.314
	ATO	10,864	0.673	0.463	0.082	2.558
	Cashflow	10,864	0.043	0.068	-0.152	0.223
	ListAge	10,864	2.001	0.907	0	3.178
	FirmAge	10,864	2.743	0.365	1.609	3.367
	Big4	10,864	0.061	0.239	0	1

4. Empirical Results and Analysis

4.1. Benchmark Regression Results Analysis

Before estimation, this study conducts a Variance Inflation Factor (VIF) test to check for multicollinearity. The results show that the VIF values of the main model are all less than 10, indicating no significant multicollinearity issues.

Table 4 reports the benchmark regression results examining the impact of industry integration on firms' export complexity. Column (1) tests the basic effect of industry integration (*Fusion*) on firms' export complexity (*esi*), without controlling for industry and year fixed effects. Column (2) adds industry and year fixed effects. Column (3) includes control variables but does not control for fixed effects. Column (4) includes both control variables and controls for industry and year fixed effects.

The results show that the estimated coefficients of the core explanatory variable, *Fusion*, are significantly positive at the 5% level across all columns, indicating that industry integration significantly promotes firms' export technological complexity, thus validating Hypothesis H1.

Among control variables, the coefficients for leverage ratio (*Lev*), return on assets (*ROA*), and years since listing (*ListAge*) are significantly different from zero, suggesting that debt levels, profitability, and firm age significantly affect export complexity.

Table 4. Benchmark Regression Results

Variables	(1)	(2)	(3)	(4)
	esi			
Fusion	361.515***	543.246***	134.439**	384.092***
	(3.503)	(5.733)	(2.443)	(3.920)
Size			-4.343	8.433
			(-0.409)	(0.506)
Lev			-392.625***	-176.255*
			(-5.409)	(-1.724)
ROA			-1,592.120***	-1,596.704**
			(-2.926)	(-2.092)
ROE			170.516	679.362**
			(0.651)	(2.145)
ATO			61.500***	-58.761
			(2.768)	(-1.545)
Cashflow			356.561**	354.833**
			(2.244)	(1.967)
ListAge			-174.132***	-139.217***
			(-11.782)	(-5.878)
FirmAge			-243.062***	-152.856***
			(-7.569)	(-2.696)
Big4			34.694	10.720
			(0.774)	(0.133)
Constant	515.054***	892.573***	1,852.894***	1,487.833***
	(16.306)	(2.850)	(7.838)	(2.921)
Industry Fixed Effects	NO	YES	NO	YES
Year Fixed Effects	NO	YES	NO	YES
Observations	10,864	10,864	10,864	10,864
R^2	0.004	0.188	0.058	0.209

*Note: t-values are reported in parentheses. *, *, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

4.2. Robustness Checks

To verify the reliability of the benchmark regression results, this study conducts robustness checks from four perspectives: (1) excluding samples from municipalities, (2) using propensity score matching (PSM), (3) adjusting the sample period, and (4) applying instrumental variable (IV) methods.

4.2.1. Regression Excluding Municipalities

Considering that Beijing, Tianjin, Shanghai, and Chongqing, as municipalities directly under the central government, possess unique policy resources and economic structures that may interfere with the regression results, this study re-estimates the model after excluding these four municipalities.

As shown in Table 5, the estimated coefficients of the core explanatory variable, *Fusion,* remain significantly positive at the 1% level across all specifications, indicating that the positive effect of industry integration on export technological complexity remains robust even after removing the special municipality samples.

Table 5. Robustness Test Results: Excluding Municipalities

Variables	(1)	(2)	(3)	(4)
	esi			
Fusion	641.374***	701.372***	360.182***	522.102***
	(5.430)	(6.548)	(5.482)	(4.725)
Size			0.304	12.308
			(0.024)	(0.616)
Lev			-430.861***	-183.251
			(-5.180)	(-1.568)
ROA			-1,278.133**	-1,642.855*
			(-2.038)	(-1.853)
ROE			2.123	644.690*
			(0.007)	(1.783)
ATO			85.089***	-47.948
			(3.229)	(-1.041)
Cashflow			69.334	140.207
			(0.371)	(0.661)
ListAge			-182.816***	-140.175***
			(-10.625)	(-5.072)
FirmAge			-242.722***	-175.699***
			(-6.564)	(-2.721)
Big4			45.801	66.892
			(0.737)	(0.571)
Constant	514.384***	924.762***	1,777.299***	1,485.409**
	(15.513)	(2.639)	(6.336)	(2.501)
Industry Fixed Effects	NO	YES	NO	YES
Year Fixed Effects	NO	YES	NO	YES
Observations	8,301	8,301	8,301	8,301
R^2	0.011	0.197	0.067	0.218

*Note: t-values are reported in parentheses. *, *, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

4.2.2. Propensity Score Matching (PSM)

To address potential sample selection bias, this study adopts the Propensity Score Matching (PSM) method. Sample selection bias arises when the assignment of the Fusion variable is influenced by confounding factors, making the estimated effect of industry integration on export complexity potentially spurious.

Specifically, logistic regression is used to assign scores based on control variables, calculating a composite score for each firm. Based on the caliper matching and 1:1 nearest neighbor matching principles, treated firms are matched with control firms with similar propensity scores, and unmatched observations are excluded.

As shown in Table 6, the coefficients of *Fusion* remain significantly positive across all specifications, indicating that the promoting effect of industry integration on export technological complexity remains robust after addressing sample selection bias.

Table 6. Robustness Test Results: Propensity Score Matching (PSM)

Variables	(1)	(2)	(3)	(4)
	esi			
Fusion	330.604***	535.235***	107.140*	369.631***
	(3.088)	(5.494)	(1.801)	(3.709)
Size			-0.472	13.168
			(-0.042)	(0.777)
Lev			-426.126***	-224.510**
			(-5.615)	(-2.189)
ROA			-1,141.899**	-1,407.092*
			(-2.003)	(-1.781)
ROE			-45.775	534.306
			(-0.168)	(1.618)
ATO			65.418***	-49.671
			(2.794)	(-1.287)
Cashflow			315.111*	365.004**
			(1.881)	(2.008)
ListAge			-177.705***	-141.194***
			(-11.253)	(-5.748)
FirmAge			-257.811***	-170.378***
			(-7.516)	(-2.875)
Big4			91.787*	84.802
			(1.759)	(0.892)
Constant	527.331***	893.188***	1,837.204***	1,454.041***
	(16.413)	(2.861)	(7.364)	(2.796)
Industry Fixed Effects	NO	YES	NO	YES
Year Fixed Effects	NO	YES	NO	YES
Observations	9,596	9,596	9,596	9,596
R^2	0.003	0.188	0.062	0.212

*Note: t-values are reported in parentheses. *, *, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

4.2.3. Changing the Sample Period

Considering that special periods such as the global financial crisis (2008) and stock market crash (2015) may cause economic volatility that interferes with regression results, this study redefines the sample period by excluding data from 2008 and 2015.

As shown in Table 7, the estimated coefficients for the core explanatory variable, *Fusion*, remain significantly positive at the 1% level across all specifications. This indicates that the positive impact of industry integration on firms' export technological complexity remains robust even after adjusting the sample period.

Table 7. Robustness Test Results: Changing the Sample Period

Variables	(1)	(2)	(3)	(4)
	esi			
Fusion	315.437***	516.207***	376.014***	334.615***
	(2.910)	(5.239)	(3.730)	(3.349)
Size			3.869	11.355
			(0.238)	(0.673)
Lev			-154.819	-182.058*
			(-1.532)	(-1.781)
ROA			-971.796	-1,001.321
			(-1.199)	(-1.236)
ROE			430.482	353.048
			(1.253)	(1.024)
ATO			-30.185	-45.478
			(-0.793)	(-1.190)
Cashflow			312.770	322.959*
			(1.637)	(1.697)
ListAge			-181.583***	-170.521***
			(-7.222)	(-6.847)
FirmAge			-166.699***	-122.299**
			(-3.071)	(-2.120)
Big4			73.717	71.709
			(0.775)	(0.757)
Constant	512.895***	862.150***	1,571.762***	1,376.593***
	(16.151)	(2.865)	(3.202)	(2.701)
Industry Fixed Effects	NO	YES	NO	YES
Year Fixed Effects	NO	YES	NO	YES
Observations	7,869	7,869	7,869	7,869
R^2	0.003	0.195	0.146	0.221

*Note: t-values are reported in parentheses. *, *, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

4.2.4. Instrumental Variable (IV) Approach

The benchmark regression may suffer from endogeneity issues caused by reverse causality, whereby the improvement in export technological complexity may in turn promote industry integration. To address this problem, this study employs an instrumental variable (IV) approach.

Specifically, the average industry-level integration (*iv*) is selected as the instrumental variable. Regarding relevance, firms within the same industry tend to exhibit similar levels of integration, making the industry average highly correlated with individual firms' integration levels. Regarding exogeneity, the industry average is not directly affected by the export complexity of any single firm, thus satisfying the exogeneity condition required for a valid instrument.

The IV regression results are reported in Table 8. The first-stage regression shows that the coefficient on iv is positive and significant at the 1% level, indicating a strong correlation between iv and the core explanatory variable Fusion. In the second-stage regression, Fusion remains significantly positive in affecting firms' export complexity (*esi*).

Additionally, the Kleibergen-Paap rk LM test rejects the null hypothesis of under-identification, and the Kleibergen-Paap rk Wald F statistic exceeds the critical value, rejecting the weak instrument hypothesis. These results further confirm the validity of the chosen instrument.

In conclusion, after addressing potential endogeneity, the positive effect of industry integration on firms' export technological complexity remains robust, confirming the internal validity of the study's conclusions.

Table 8. Instrumental Variable Regression Results

Variables	(1)	(2)
	Fusion	*esi*
iv	0.968***	
	(11.514)	
Fusion		548.280**
		(2.176)
Size	0.004	12.332
	(1.157)	(0.717)
Lev	-0.075***	-210.939*
	(-3.440)	(-1.919)
ROA	0.011	-1,409.663*
	(0.075)	(-1.776)
ROE	-0.001	535.392
	(-0.012)	(1.616)
ATO	0.012	-51.916
	(1.537)	(-1.325)
Cashflow	-0.020	369.472**
	(-0.566)	(2.034)
ListAge	-0.017***	-138.064***
	(-3.583)	(-5.217)
FirmAge	-0.045***	-162.227***
	(-3.247)	(-2.627)
Big4	0.056***	74.716
	(3.579)	(0.766)
Constant	0.081	1,408.691***
	(0.939)	(2.741)
Industry Fixed Effects	YES	YES
Year Fixed Effects	YES	YES
Observations	9,596	9,596
R^2	0.129	0.208

*Note: t-values are reported in parentheses. *, *, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

5. Further Analysis

5.1. Heterogeneity Analysis

The impact of industry integration on firms' export technological complexity may vary across different dimensions. This section conducts further analysis based on three aspects: regional heterogeneity, ownership type, and CEO duality.

While the previous regressions have shown that industry integration generally enhances firms' export complexity, due to significant differences in regional environments, ownership structures, and corporate governance, this effect may differ across sample groups. Thus, further analysis is conducted from the perspectives of geographical location, property rights, and governance structure.

5.1.1. Regional Heterogeneity

To examine regional differences in the impact of industry integration on export technological complexity, this study divides China into three traditional regions—eastern, central, and western—and conducts subgroup regressions accordingly.

As shown in Table 9, the level of industry integration has a positive effect on export complexity across all regions, but the strength of the effect varies. The regression coefficient for the central region (2,208.159, p<0.01) is significantly higher than that for the eastern region (288.579, p<0.05), while the coefficient for the western region (302.538) is not statistically significant.

Although the eastern region enjoys a more mature foundation for integration and better digital infrastructure, its marginal improvement space is relatively limited. In contrast, the central region is at a critical stage of industrial transformation, with accelerated integration processes driven by combined policy support and corporate initiatives, releasing a stronger upgrading effect on export structures. On the other hand, the western region faces constraints such as a weak economic base, shortages of innovation factors, and a less diversified industrial structure, resulting in smaller export scales and insufficient R&D investment by firms. Consequently, industry integration in the western region has not effectively activated the mechanisms for improving export complexity, leading to noticeable regional disparities: the positive effects of industry integration on export complexity are significant in the eastern and central regions but not in the western region.

Table 9. Regional Heterogeneity: Subgroup Regression Results

Variables/Groups	(1)	(2)	(3)
	Eastern Region	Central Region	Western Region
Fusion	288.579**	2,208.159***	302.538
	(2.546)	(2.590)	(0.531)
Size	27.775	-43.490	24.531
	(1.272)	(-1.185)	(0.681)
Lev	-191.182	80.570	-524.404**
	(-1.461)	(0.354)	(-2.018)
ROA	-1,235.111	-2,669.898*	-313.172
	(-1.212)	(-1.695)	(-0.150)
ROE	475.430	1,196.000*	-401.356
	(1.027)	(1.877)	(-0.561)
ATO	-77.902	-83.323	142.653
	(-1.609)	(-1.196)	(1.247)
Cashflow	376.146*	448.829	268.515
	(1.733)	(0.985)	(0.488)
ListAge	-134.972***	-181.300***	-103.004
	(-4.683)	(-2.924)	(-1.459)
FirmAge	-104.192	-465.771***	-163.915
	(-1.592)	(-2.792)	(-1.073)
Big4	-44.000	407.341*	541.407
	(-0.408)	(1.845)	(1.375)
Constant	688.718	3,813.509***	230.802
	(1.200)	(3.515)	(0.271)
Industry Fixed Effects	YES	YES	YES
Year Fixed Effects	YES	YES	YES
Observations	6,351	1,888	1,357
R^2	0.230	0.255	0.176

*Note: t-values are reported in parentheses. *, *, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

5.1.2. Ownership Heterogeneity

A firm's ownership structure determines its resource allocation approach, incentive mechanisms, and strategic behavior logic, which may also influence the implementation of industry integration.

State-owned enterprises (SOEs) often benefit from policy support and factor guarantees but may suffer from weaker incentives and innovation inertia, leading to lower motivation for integration. In contrast, non-state-owned enterprises (non-SOEs) rely more heavily on market mechanisms, showing stronger integration motivation through flexible resource allocation and innovation-driven incentives (Zhu Lei et al., 2019).

As shown in Columns (1) and (2) of Table 10, industry integration significantly enhances export technological complexity for non-SOEs (coefficient = 401.840, $p<0.01$), whereas for SOEs, the coefficient (272.334) is lower and not statistically significant.

This result suggests that private firms, driven by market orientation and the pursuit of efficiency and profit, are more proactive in implementing integration strategies and improving export product value through technological upgrading and servitization. In contrast, despite having resource advantages, SOEs experience slower integration progress due to path dependency and managerial inertia, making it difficult to achieve significant improvements in export structure in the short term.

5.1.3. Governance Structure Heterogeneity

Corporate governance structure is a key component of internal institutional arrangements, directly affecting strategic execution efficiency and resource allocation. Among various governance structures, "CEO duality" refers to the chairman concurrently serving as CEO, reflecting a high concentration of internal power. Research suggests that power concentration can improve strategic decision-making efficiency but may also weaken supervisory mechanisms and increase governance risks (Kaplan, 2009). Excessive concentration of power may lead to information manipulation and supervision failures, affecting the long-term health of corporate governance (Stiles & Taylor, 2001).

Thus, it is hypothesized that in firms with CEO duality, greater governance risks may reduce the effectiveness of industry integration strategies in transforming export product structures.

To test this, firms are grouped based on whether CEO duality is present, and subgroup regressions are conducted. As shown in Columns (3) and (4) of Table 10, for firms with CEO duality, industry integration has a stronger effect on export complexity (coefficient = 389.704, $p<0.01$) compared to firms without CEO duality (coefficient = 313.153, $p<0.05$).This indicates that power concentration accelerates the implementation of integration strategies and enhances organizational coordination efficiency, leading to faster coupling between service elements and export products. However, it should also be noted that supervision deficiencies under centralized structures may affect the sustainability of integration quality, highlighting the important moderating role of governance structure.

Table 10. Firm-Level Heterogeneity: Subgroup Regression Results

Variables/Groups	Ownership Type		CEO Duality	
	(1)	(2)	(3)	(4)
	SOE	Non-SOE	Dual Role	No Dual Role
Fusion	272.334	401.840***	389.704***	313.153**
	(1.329)	(3.617)	(2.669)	(2.553)
Size	1.621	44.370*	22.339	11.142
	(0.067)	(1.757)	(0.651)	(0.583)
Lev	-136.263	-280.416**	-270.612	-189.704
	(-0.846)	(-2.019)	(-1.355)	(-1.631)
ROA	-235.837	-1,333.046	-670.926	-1,549.995*
	(-0.160)	(-1.358)	(-0.478)	(-1.676)
ROE	350.822	165.444	-22.007	645.776*
	(0.660)	(0.348)	(-0.035)	(1.683)
ATO	-54.876	-19.457	-17.634	-52.406
	(-0.997)	(-0.352)	(-0.205)	(-1.270)
Cashflow	18.554	552.568**	393.711	414.328**
	(0.064)	(2.354)	(1.068)	(1.991)
ListAge	-179.005***	-144.661***	-81.917*	-163.061***
	(-3.338)	(-4.970)	(-1.934)	(-5.640)
FirmAge	-96.850	-179.588***	-151.170	-180.320***
	(-0.843)	(-2.629)	(-1.599)	(-2.631)
Big4	110.690	57.853	-178.967	124.079
	(0.926)	(0.389)	(-1.224)	(1.185)
Constant	1,435.862**	902.929	682.673	1,686.649***
	(2.083)	(1.198)	(0.762)	(2.932)
Industry Fixed Effects	YES	YES	YES	YES
Year Fixed Effects	YES	YES	YES	YES
Observations	4,055	5,541	2,327	7,179
R^2	0.169	0.231	0.237	0.205

*Note: t-values are reported in parentheses. *, *, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

5.2. Mechanism Analysis

To further explore the internal pathways through which industry integration improves firms' export technological complexity, this study conducts a two-step mechanism analysis based on the previous empirical findings. The focus is on examining the roles of three mechanism variables: technological innovation capability, foreign direct investment (FDI), and resource allocation efficiency.

The models are constructed as follows:

$$M_{i,t} = \gamma_0 + \gamma_1 Fusion_{i,t} + \gamma Control_{i,t} + \varphi_i + \mu_t + \varepsilon_{i,t} \tag{5}$$

where Mechanismit\text {Mechanism}_{it}Mechanismit represents the mechanism variables, including technological innovation capability, FDI absorption capacity, and resource allocation efficiency. The remaining model specifications are consistent with the baseline regressions.

5.2.1. Technological Innovation Capability

Technological innovation capability is one of the core driving forces behind the enhancement of firms' export technological complexity. With the advancement of industry integration, firms have not only increased their investment in R&D activities but also, through servitization transformation, discovered new innovation opportunities arising from the differentiated and personalized demands of customers (Wang, Liu, & Wang, 2022). Specifically, the embedding of service elements enables firms to interact more closely with customers, allowing them to better understand market needs and translate these insights into motivations for product innovation. This two-way interaction not only enhances firms' technological innovation capabilities but also promotes the technological sophistication of their export products.

To verify this mechanism, this study employs firms' R&D expenditures (*RD*) and the number of patents (*Patent*) as proxy variables for technological innovation capability. The regression results reported in Columns (1) and (2) of Table 11 show that the coefficients of industry integration on both *RD* and *Patent* are significantly positive at the 1% significance level. This finding indicates that servitization transformation significantly increases firms' willingness to invest in R&D and improves their capacity for technological output. Moreover, the enhancement of technological innovation capability enables firms to offer more high-value-added and technology-intensive products in the international market, thereby further advancing the technological complexity of their exports. Thus, Hypothesis H1-a is validated.

5.2.2. Foreign Direct Investment (FDI)

Foreign direct investment (*FDI*) is not only a source of capital injection but also an important vehicle for technology transfer and the dissemination of management expertise. The advanced technologies, management practices, and international certification systems introduced by foreign firms provide essential support for domestic enterprises to overcome technological bottlenecks and transition toward high value-added products (Blomstrom & Kokko, 2001; Rodrik, 2013). Such advantages in technology transfer and knowledge spillover significantly enhance firms' export technological complexity.

Furthermore, as industry integration advances, firms' advantages in organizational standardization and external compatibility become increasingly evident, making them more attractive to high-quality foreign investment projects (Young & Lan, 1997). The regression results reported in Column (4) of Table 11 show that the coefficient of industry integration on *FDI* absorption capability is significantly positive, indicating that servitization transformation notably strengthens firms' ability to attract foreign capital. This enhanced *FDI* absorption capability not only provides additional funding but, more importantly, facilitates technology transfer and the enhancement of innovation capacity, thereby laying a solid foundation for further improvements in firms' export technological complexity. Accordingly, Hypothesis H1-b is validated.

Table 11. Mechanism Test Regression Results

Variables	(1)	(2)	(3)	(4)
	RD	*Patent*	*FDI*	*Overinvest*
Size	-0.001***	0.523***	0.020*	0.031***
	(-4.868)	(17.246)	(1.836)	(2.709)
Lev	-0.006***	-0.260	-0.004	0.129**
	(-3.377)	(-1.579)	(-0.798)	(1.964)
ROA	0.025*	0.345	0.009	0.106
	(1.847)	(0.342)	(0.299)	(0.197)
ROE	0.004	0.979**	-0.003	0.305
	(0.704)	(2.036)	(-0.222)	(1.644)
ATO	0.006***	0.213***	0.002	-0.028
	(6.883)	(3.209)	(1.448)	(-1.488)
Cashflow	0.014***	-0.658**	-0.011	0.220
	(3.352)	(-2.299)	(-1.473)	(1.037)
ListAge	0.000	0.016	-0.001	0.048*
	(0.456)	(0.498)	(-0.856)	(1.705)
FirmAge	-0.004***	-0.177**	0.003	0.038*
	(-3.842)	(-2.117)	(1.628)	(1.700)
Big4	0.001	0.116	0.002	-0.039
	(0.622)	(0.756)	(0.797)	(-1.434)
Constant	0.037***	-10.088***	0.010	-0.430
	(5.678)	(-14.879)	(0.647)	(-1.344)
Industry Fixed Effects	YES	YES	YES	YES
Year Fixed Effects	YES	YES	YES	YES
Observations	9,596	9,596	9,596	8,283
R^2	0.392	0.434	0.321	0.412

*Note: t-values are reported in parentheses. *, *, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

5.2.3. Resource Allocation Efficiency

Previous studies have emphasized that optimizing resource allocation can significantly improve firms’ production efficiency, thereby promoting technological innovation and enhancing product sophistication (Paus & Gallagher, 2017). Especially under the context of servitization, firms have optimized their resource deployment, improved fine-grained management in production processes, and reduced waste and inefficient investments, thus providing essential support for upgrading export technological complexity.

As shown in Column (4) of Table 11, there is a significant negative correlation between overinvestment (*Overinvest*) and resource allocation efficiency, indicating that reducing overinvestment enables firms to use their resources more efficiently and to focus on producing high-technology products. Therefore, industry integration enhances firms' resource allocation efficiency, which indirectly promotes the improvement of their export technological complexity, thereby confirming Hypothesis H1-c.

Table 12. Mechanism Test Results

Variables	(1)	(2)	(3)	(4)
	RD	*Patent*	*FDI*	*Overinvest*
Size	-0.001***	0.523***	0.020*	0.031***
	(-4.868)	(17.246)	(1.836)	(2.709)
Lev	-0.006***	-0.260	-0.004	0.129**
	(-3.377)	(-1.579)	(-0.798)	(1.964)
ROA	0.025*	0.345	0.009	0.106
	(1.847)	(0.342)	(0.299)	(0.197)
ROE	0.004	0.979**	-0.003	0.305
	(0.704)	(2.036)	(-0.222)	(1.644)
ATO	0.006***	0.213***	0.002	-0.028
	(6.883)	(3.209)	(1.448)	(-1.488)
Cashflow	0.014***	-0.658**	-0.011	0.220
	(3.352)	(-2.299)	(-1.473)	(1.037)
ListAge	0.000	0.016	-0.001	0.048*
	(0.456)	(0.498)	(-0.856)	(1.705)
FirmAge	-0.004***	-0.177**	0.003	0.038*
	(-3.842)	(-2.117)	(1.628)	(1.700)
Big4	0.001	0.116	0.002	-0.039
	(0.622)	(0.756)	(0.797)	(-1.434)
Constant	0.037***	-10.088***	0.010	-0.430
	(5.678)	(-14.879)	(0.647)	(-1.344)
Industry Fixed Effects	YES	YES	YES	YES
Year Fixed Effects	YES	YES	YES	YES
Observations	9,596	9,596	9,596	8,283
R^2	0.392	0.434	0.321	0.412

6. Summary

This study investigates the impact of industry integration on firms' export technological complexity and its underlying mechanisms, based on an empirical analysis of Chinese A-share listed companies from 2007 to 2019. The findings reveal that as industry integration progresses, the technological complexity of firms’ export products improves significantly. Specifically, industry integration enhances firms’ technological innovation capability by embedding service elements into production processes, thereby encouraging greater investment in R&D and promoting product differentiation and upgrading. Additionally, industry integration strengthens firms' ability to attract high-quality foreign direct investment (*FDI*), which brings advanced technologies and management expertise, helping firms overcome technological bottlenecks and transition toward high value-added exports. Moreover, by optimizing resource allocation efficiency, firms can reduce inefficient investments and better utilize capital and technology, providing strong support for the production of sophisticated export products.

Heterogeneity analysis further indicates that firms in the eastern region and non-state-owned enterprises benefit more significantly from industry integration, particularly in terms of improvements in technological innovation and resource allocation efficiency. In contrast, firms located in the central and western regions and state-owned enterprises derive relatively fewer benefits, highlighting the moderating effects of regional and ownership differences. These findings suggest that while industry integration promotes export sophistication at the firm level, its effectiveness varies across different contexts, implying the need for regionally differentiated policy interventions.

Based on these results, this study proposes several policy recommendations. First, the government should enhance support for service-oriented manufacturing, encouraging firms to integrate service elements to stimulate technological innovation and increase product value-added, thus driving the sophistication of export structures. Second, policies should focus on attracting high-technology *FDI* by improving the investment environment and facilitating technology spillovers to strengthen domestic innovation capabilities. Third, efforts should be made to promote better resource allocation efficiency among firms by reducing ineffective investments and enhancing production and capital utilization efficiency. Additionally, more infrastructure investment is needed in the central and western regions, particularly in digital technologies, information systems, and logistics, to help firms integrate into the industry integration process and enhance global competitiveness. Finally, policymakers should tailor development strategies to the characteristics of different regions to promote balanced regional development and maximize the benefits of industry integration nationwide.

References

[1] M. Blomstrom, A. Kokko, Foreign direct investment and spillovers of technology, Int. J. Technol. Manag. 22 (5-6) (2001) 435-454.

[2] L. Branstetter, N.R. Lardy, The China Conundrum: Understanding Chinese Innovation and Technology Policy, Peterson Institute for International Economics (2018).

[3] G. Cainelli, R. Evangelista, M. Savona, Innovation and economic performance in services: A firm-level analysis, Camb. J. Econ. 30(3) (2015) 435-458.

[4] G. Cainelli, M. Mazzanti, R. Zoboli, Environmental Innovations in Services: Manufacturing-Services Integration and Policy Transmissions, Elsevier (2015).

[5] R. Cui, H. Song, D. Li, Global value chain embeddedness, technology spillover, and enterprise innovation, Int. Rev. Econ. Financ. (2024).

[6] R. Hausmann, J. Hwang, D. Rodrik, What you export matters, J. Econ. Growth 12(1) (2007) 1-25.

[7] I. Huseyni, E. Cakmak, Determinants of export sophistication: Does digitalization matter?, J. Int. Econ. 126 (2020) 103293.

[8] R.S. Kaplan, Risk management and the strategy execution system, Balanced Scorecard Report 10(2) (2009) 23-45.

[9] S.A. Khan, S. Ullah, I. Saeed, S.I. Zaman, Promoting green growth through identification of sustainable strategies: a hybrid approach, Int. J. Emerg. Mark. (2024).

[10] M. Kohtamäki, S. Einola, R. Rabetino, Exploring servitization through the paradox lens: Coping practices in servitization, Ind. Mark. Manag. 89 (2020) 105-116.

[11] H. Liu, H. Zhao, S. Li, Future social change of manufacturing and service industries: Service-oriented manufacturing under the integration of innovation-flows drive, Sci. Direct (2023).

[12] P. Li, Y. Cheng, W.Y. Song, F. Tao, Manufacturing services collaboration: connotation, framework, key technologies, and research issues, J. Manuf. Syst. 67 (2023) 102-115.

[13] V. Parida, D.R. Sjödin, S. Lenka, Developing global service innovation capabilities: How global manufacturers address the challenges of market heterogeneity, J. Technol. Manag. 5(2) (2015) 35-56.

[14] E. Paus, K.P. Gallagher, Trade, technology and industrial policy: Leveraging innovation for export success, Cambridge University Press (2017).

[15] D. Rodrik, Unconditional convergence? Asia and the Pacific in global economic governance, Rev. Int. Polit. Econ. 20(5) (2013) 888-904.

[16] M. Scerri, R. Agarwal, Service enterprise productivity in action: Measuring service productivity, J. Serv. Theory Pract. 27(3) (2018) 89.

[17] J.R. Silva, C.C. Simões, Portuguese exports and FDI: Observations from the firms' perspective, China-USA Bus. Rev. 11(1) (2012) 49-63.

[18] P. Stiles, B. Taylor, Boards at work: How directors view their roles and responsibilities, Harvard Business Press 19(3) (2001) 123-137.

[19] Y. Sun, C. Xu, Y. Han, K. Huang, The nexus of foreign direct investment and agricultural productivity: Does absorptive capacity matter?, Kybernetes (2025).

[20] K. Wang, D. Liu, Y. Wang, Servitization of manufacturing in the new ICTs environment: Drivers and challenges, Technol. Forecast. Soc. Change 174 (2022) 121268.

[21] L. Wang, X. Liu, Z. Wang, The impact of service integration on manufacturing firms' export complexity: An empirical study, J. Bus. Res. 78 (2022) 123-134.

[22] Y. Wang, X. Liu, X. Li, Technology innovation and export complexity in manufacturing, J. Int. Trade 21(4) (2022) 95-112.

[23] D. Wu, Y. Pi, Digital technologies and product-service systems: A synergistic approach for manufacturing firms under a circular economy, J. Digit. Econ. 77 (2023) 75.

[24] S. Young, P. Lan, Technology transfer to China through foreign direct investment, Reg. Stud. 31(7) (1997) 669-679.

[25] M. Zhou, X. Liu, T. Buck, FDI, technological capability and the upgrading of Chinese exporters, World Dev. 154 (2022) 105882.

[26] X.Z. Bao, Research on the impact of export sophistication on the green transformation of manufacturing: An empirical analysis based on a nonlinear panel model, Price Theory Pract. (2024) 184-188+231.

[27] K.Z. Dai, The impact and mechanism of technology market development on export sophistication, China Ind. Econ. (2018) 117-135.

[28] L. Dang, X.S. Li, S. Shen, The impact of digital transformation on intermediate goods export sophistication in manufacturing industries, Int. Trade Issues (2021) 32-47.

[29] P. Dong, Intellectual property protection, local technology development and firms' export sophistication, Technol. Econ. Manag. Res. (2024) 27-32.

[30] Y. Hu, W. Li, Does digital infrastructure improve export sophistication? Empirical evidence based on national-level data, J. Xi'an Univ. Technol.

[31] P. Jiao, R.X. Tian, Mechanism study on digital innovation enabling the deep integration of modern service industries and advanced manufacturing, J. Guangdong Univ. Financ. Econ. 38(01) (2023) 31-44.

[32] J.M. Liu, X.Y. Ma, The impact of heterogeneous firm agglomeration on export sophistication, Technol. Econ. Manag. Res. (2024) 1-6.

[33] B. Liu, T. Pan, The impact of artificial intelligence on the value chain division of labor in manufacturing, Quant. Econ. Technol. Econ. Res. 34(5) (2020) 210-225.

[34] J.L. Liu, J.K. Liu, Y.Y. Chen, Does the cross-border e-commerce pilot zone improve urban manufacturing export sophistication?, World Econ. Res. (2024) 58-71+135.

[35] J.J. Li, M.X. Jiang, C.S. Zhang, How does digital economy development affect urban export sophistication? Theoretical model and empirical evidence, Explor. Int. Econ. Trade 40(11) (2024) 57-73.

[36] J.M. Li, L. Zhang, Research on the impact of government R&D subsidies on export sophistication, Product. Res. (2024) 11-19+161.

[37] L. Li, H. Zhao, Study on the relationship between "industry integration" and carbon emission efficiency, Econ. Geogr. 38(05) (2021) 71-79.

[38] H. Niu, Z.Y. Yu, J.H. Chen, Digital transformation and high-quality export development: A perspective based on export sophistication, Foreign Econ. Manag. 46(07) (2024) 53-68.

[39] S. Pan, S.F. Tang, D.Z. Ye, Y.Y. Yang, The impact of digital economy on export sophistication: An empirical analysis based on urban panel data, Financ. Trade Res. 35(02) (2024) 15-30.

[40] B. Sheng, Q.L. Mao, Does import trade liberalization affect the export sophistication of China's manufacturing sector?, World Econ. 40(12) (2017) 52-75.

[41] G.H. Song, Y.D. Dong, Can the development of public services promote firms' export sophistication?, Int. Bus. (Univ. Int. Bus. Econ. J.) (2024) 39-55.

[42] S.Y. Wang, L.K. Zheng, Does servitization of manufacturing promote the upgrading of export products? Evidence from product quality and export sophistication perspectives, Int. Trade Issues 42(10) (2019) 112-123.

[43] W. Wang, Y.Q. Li, Digital economy, industry integration and total factor productivity of China's manufacturing industry, J. Shanghai Univ. Int. Bus. Econ. 31(01) (2024) 5-22.

[44] X. Zhang, J. Zhong, H.F. Wang, Measurement and influencing factors of the integration level between China's advanced manufacturing and modern services, Financ. Econ. Theory Pract. 43(03) (2022) 135-141.

[45] C.M. Zhao, T.T. Chu, Research on the impact of smart manufacturing on export sophistication, New Vision (2025) 5-17.

[46] Z.P. Zheng, Y.D. Wang, International technology spillovers, human capital and export sophistication, Economist (2017) 97-104.

[47] L. Zhu, X. Chen, C.Y. Wang, The impact of mixed ownership reform on innovation in state-owned enterprises, Econ. Manag. 41(11) (2019) 72-91.