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Research on the Impact of the U.S. Export Controls on the Firms' Export Technology Complexity: Evidence from China's Manufacturing Sector

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Abstract

As Chinese manufacturing enterprises became more deeply integrated into global value chains, they faced increasingly restrictive U.S. export controls that limited their access to foreign technologies and critical intermediate inputs. Using firm-level data from Chinese listed manufacturing firms over 2006–2015 and the U.S. Entity List, this paper systematically examines the impact of export controls on China's export technology complexity and explores the underlying mechanisms. The study shows that U.S. export controls significantly reduce manufacturing enterprises' export technological complexity. The negative effect is more pronounced among enterprises in eastern China, state-owned enterprises, large enterprises, and enterprises operating in high-technology industries. Mechanism analysis shows that export controls suppress the growth of export technological complexity by increasing transaction costs and disrupting supply chains. Although the disruption of innovation chains may stimulate firms' indigenous innovation, the overall effect of export controls remains negative. Our findings provide theoretical and practical insights for China's strategies to respond to export controls, enhance the technology complexity of manufacturing exports, and strengthen its position in the global value chain.

Keywords: export controls; manufacturing firms; export technology complexity; Entity List; multi-period difference-in-differences

1. Introduction

The manufacturing sector has long been a cornerstone of China's national economy and a central driver of economic growth, export expansion, and industrial upgrading. Since 2010, China has maintained the world's largest manufacturing value added, reflecting both the scale advantage of its industrial system and its increasingly important position in global value chains. Alongside this expansion, the scale of China's manufacturing exports and the technology complexity of its exported products have continued to increase, indicating a gradual transition from labor-intensive production toward more technology-intensive activities. This upgrading process, however, has also increased the exposure of Chinese manufacturing firms to external technological constraints, especially in knowledge-intensive sectors that depend on imported core technologies, specialized equipment, and intermediate inputs.

U.S. export control policy toward China has evolved over time. Before the recent period of high-intensity geopolitical and technological confrontation, export controls were already an important policy instrument through which access to specific technologies,



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products, and firms could be restricted. During this pre-escalation phase, such measures were less comprehensive than the contemporary export-control regime, but they nevertheless created meaningful frictions for affected firms by raising transaction costs, disrupting access to foreign suppliers, and constraining technology-related interactions. Examining this earlier period is therefore important for understanding the foundational mechanisms through which export controls affect firm behavior and export upgrading before policy restrictions become broader and more intensive.

This paper focuses on the earlier phase of U.S. export controls against China before the emergence of the contemporary high-intensity export-control regime. Using Chinese listed manufacturing firms from 2006 to 2015, this study constructs a multi-period difference-in-differences model to systematically examine the impact of export controls on the export technology complexity of China's manufacturing sector. Specifically, the analysis investigates three potential mechanisms—rising transaction costs, supply chain disruptions, and innovation chain constraints—and further explores heterogeneous effects across firm ownership, firm size, regions, and industries. The findings not only enrich the literature on the economic consequences of export controls but also provide important policy implications for enhancing export technology complexity and promoting the high-quality development of China's manufacturing industry under external technological containment.

The marginal contributions of this paper are as follows. First, in terms of research perspective, this paper contributes to the emerging literature on export controls, technogeopolitical fragmentation, and industrial upgrading by examining how U.S. export controls affect the export technology complexity of China's manufacturing firms. While existing studies have primarily focused on the effects of export controls on innovation, trade performance, and firm behavior, relatively limited attention has been paid to their implications for export technological upgrading. By linking export controls with export technology complexity, this study extends the existing literature on external technological restrictions and industrial upgrading.

Second, this paper provides a unified analytical perspective by examining three distinct channels—transaction costs, supply chain disruptions, and innovation chain constraints—through which export controls may affect export technology complexity. By analyzing these mechanisms within a common framework, the study contributes to a better understanding of the multiple pathways linking export controls and industrial upgrading.

Third, in terms of research dimensions, this paper further investigates the heterogeneous effects of export controls across different firm ownership structures, firm sizes, regions, and industries. Such analysis provides a more comprehensive understanding of how export controls generate differentiated impacts on manufacturing export upgrading under varying firm and regional characteristics, thereby offering empirical evidence for promoting the high-quality development of China's manufacturing sector under external technological restrictions.

2. Literature Review

This section reviews two closely related strands of literature to establish the theoretical foundation and identify the research gap of this study: (1) the economic effects of export controls; (2) the determinants of export technology complexity.

The first strand of literature examines the economic consequences of export controls. Existing studies generally suggest that export controls and related sanctions influence firms through multiple channels, including innovation behavior, R&D investment, trade adjustment, corporate governance, and supply chain transmission. A growing body of research finds that inclusion on the U.S. Entity List can stimulate technological innovation among affected firms, increase R&D investment, expand patent filings, and encourage

firms to shift toward basic research. These effects are primarily mediated through organizational mechanisms such as resource reallocation, technological realignment, and talent restructuring [1–4]. However, the effects of export controls are not uniformly positive. Some studies show that patent quality may decline and that the innovation response varies substantially across firm types, ownership structures, and policy-support conditions [5,6]. At the trade level, export restrictions reduce exports from allied countries such as Japan and South Korea to China and incentivize Chinese firms to pursue self-sufficiency in critical technologies [7,8]. Other studies further show that export controls may reshape corporate behavior, including ESG performance and earnings management, depending on firms' governance conditions and external pressures [9,10].

The second strand of literature investigates the determinants of export technology complexity. Existing studies have identified several important drivers, including firm innovation capability, institutional quality, policy support, digital transformation, and external economic openness. At the firm level, R&D investment, technological innovation capability, and data asset transparency are regarded as key factors that enhance firms' participation in high-technology exports and increase the value added and sophistication of export products [11]. The development of the digital economy and digital trade further promotes export technology complexity through knowledge spillovers, human capital accumulation, and industrial upgrading [12,13]. At the institutional level, environmental regulation, intellectual property protection, judicial procedure improvement, and administrative approval reform can facilitate firms' integration into global value chains by reducing transaction costs, improving resource allocation, and strengthening innovation incentives [14–18]. Policy support, including financial support, fiscal subsidies, and government attention to innovation, also contributes to export technological upgrading, with robot penetration further moderating the relationship between financial support and export technology complexity [19,20]. In addition, foreign direct investment and services trade liberalization can enhance export sophistication through technology spillovers and human capital accumulation, whereas excessive export concentration may weaken economic complexity and international competitiveness [21,22].

Taken together, these two strands of literature remain insufficiently connected. Studies on export controls have mainly examined firm innovation, R&D responses, trade adjustment, and corporate behavior, but they have paid less attention to whether and how such restrictions reshape the technology complexity embodied in firms' export baskets. Conversely, studies on export technology complexity have identified innovation capability, institutional conditions, digital transformation, and openness as key determinants, but they rarely consider export controls as an external technological constraint that may alter firms' upgrading trajectories. This study bridges these two strands by examining how U.S. export-control exposure affects firms' export technology complexity through transaction cost escalation, supply chain disruption, and innovation chain constraints during the pre-escalation phase.

3. Theoretical Analysis and Research Hypothesis

Export technology complexity reflects the technological content, knowledge intensity, and production efficiency embodied in exported products and is widely regarded as an important indicator of export quality and international competitiveness [23]. As a typical non-traditional trade policy instrument, U.S. export controls on China restrict the international flow of advanced technologies, key equipment, and related knowledge inputs, thereby exerting significant influences on firms' production activities and technological upgrading processes. On the one hand, export controls increase firms' costs of acquiring critical intermediate inputs and technological resources. On the other hand, they may

disrupt firms' connections with global supply chains and innovation networks, weakening technology spillovers and knowledge-learning opportunities. Consequently, U.S. export controls on China may affect the technology sophistication of manufacturing exports through three main channels: increased transaction costs, supply chain disruptions, and innovation chain blockages. Based on this framework, the following sections develop the theoretical analysis and corresponding research hypotheses from these three perspectives.

3.1. Transaction Cost Mechanism

According to transaction cost theory [24], cross-border transactions involve not only production costs but also institutional costs associated with information search, contract negotiation, regulatory compliance, and policy uncertainty. Recent studies indicate that geopolitical policies and export controls have significantly reshaped inter-firm linkages and exacerbated uncertainty in international transactions [25]. Against the backdrop of U.S.-China trade frictions, export controls have raised the thresholds for export licensing, expanded the scope of restrictions under the "Entity List," and intensified compliance scrutiny, thereby substantially increasing the institutional transaction costs faced by firms [26]. Firms need to invest more resources in regulatory compliance, information verification, and contract coordination, thereby increasing the cost of international business activities [27,28]. Meanwhile, export controls have heightened uncertainty and default risks in cross-border cooperation, prompting firms to adopt more conservative operational strategies and increasing the costs associated with maintaining stable international trading relationships [5,21]. Accordingly, this paper proposes Hypothesis 1:

Hypothesis 1. *U.S. export controls against China suppress firms' export technology complexity by increasing transaction costs.*

3.2. Supply Chain Disruption Mechanism

Existing supply chain literature suggests that external shocks propagate through upstream and downstream production networks and can trigger substantial restructuring of global supply chains [29–31]. Unlike conventional trade barriers, U.S. export controls are designed to selectively decouple critical supply chains from China in order to preserve U.S. technological leadership [27]. Such restrictions directly disrupt inter-firm production linkages and constrain firms that rely on imported high-tech inputs from accessing advanced technologies, critical intermediate goods, and high-end manufacturing equipment. As a consequence, affected firms may be forced to move toward lower-quality or less technologically sophisticated domestic alternatives, resulting in production downgrading and a decline in the technological content of export products [5,32]. Therefore, export-control-induced supply chain disruptions are likely to weaken firms' technological upgrading capacity and inhibit the improvement of export technology complexity. Based on the above theory, this paper proposes Hypothesis 2:

Hypothesis 2. *U.S. export controls against China suppress firms' export technology complexity by disrupting global supply chains and restricting access to high-technology intermediate inputs.*

3.3. Innovation Chain Constraints Mechanism

Although export controls are intended to restrict technological diffusion and suppress technological upgrading, existing studies suggest that such external shocks may generate innovation incentive effects among targeted firms. Empirical evidence shows that inclusion on the U.S. Entity List significantly increases firms' R&D investment, patent applications, and innovation activities, particularly among Chinese high-technology firms [1,4]. Faced with rising technological dependence and supply uncertainty, firms are incentivized to

accelerate indigenous innovation and reduce reliance on foreign technologies [3]. Meanwhile, government subsidies, resource reallocation, and technological realignment further strengthen firms' incentives to engage in independent innovation and basic research [2,5]. Although patent quality may decline in some cases, export controls overall promote firms' innovation input and technological upgrading [6], thereby contributing to improvements in export technology complexity. Based on the above analysis, this paper proposes Hypothesis 3:

Hypothesis 3. *U.S. export controls against China promote firms' export technology complexity by stimulating indigenous innovation and increasing R&D investment.*

4. Research Design

4.1. Data Sources and Sample Selection

1. Data Sources

The main data sources of this study included the China Customs Data, the China Stock Market & Accounting Research Database (CSMAR), and the U.S. Export Control Entity List. The detailed import and export product data for manufacturing firms were collected from the China Customs Import and Export Database. Data on basic company information, financial information, and R&D investment are sourced from the CSMAR listed company database. Information on manufacturing firms affected by export controls was collected from the Entity List published by the U.S. Department of Commerce. Due to the limitations of the sample range in the enterprise customs import and export database, the sample range studied in this paper is 2006–2015, and 10,530 observations were retained after matching and sorting.

2. Sample Selection

Following the identification method of enterprises affected by export controls at the micro level by [33], we selected manufacturing firms affected by U.S. export controls as the treatment group. The specific identification steps are as follows: First, we screened out Chinese entities on the U.S. Entity List, manually translated the English company names into Chinese, and manually verified them against data from search engines and a corporate information query platform's database. We matched the English and Chinese company names and obtained information such as the specific year the entity was added to the control list. Second, we match the Chinese names and specific year information of the entities included in the list with the China Customs Data to obtain product information of Chinese enterprises that were imported from or transited through the United States in the year the control was imposed. We then aggregate and organize the product information at the year level.

Third, we matched and screened product information of listed companies that imported or transited goods through the U.S. from the customs database between 2010 and 2015. Based on the product classifications defined in the second step, we identified firms that imported or transited the corresponding products during the relevant years. Simultaneously, we selected companies classified under the China Securities Regulatory Commission's industry code C, which we consider to represent manufacturing firms likely to be affected by export controls, and designated them as the treatment group.

In addition, we processed the selected samples as follows: (1) Excluded delisted firms from the sample. (2) Excluded firms designated as "ST" or "*ST" during the sample period. (3) Excluded firms listed during the sample period. (4) Excluded firms with abnormal financial data or significant missing values in key variables. (5) To mitigate the influence of outliers, all continuous variables were winsorized at the 1% level in both tails. After the above screening procedures, the final sample consisted of 444 manufacturing listed

firms affected by U.S. export controls as the treatment group and 609 manufacturing listed firms unaffected by U.S. export controls as the control group, yielding a total of 1053 firms. Table 1 reports the descriptive statistics of the relevant variables.

Table 1. Summary statistics.

Variable	Definition	Obs	Mean	Std.	Min	Max
lnESI	Export technology complexity	10,530	7.435	0.465	6.237	9.033
TSI	Export control	10,530	0.148	0.355	0.000	1.000
age	Firm age	10,530	13.851	7.953	1.000	33.000
lnsize	Firm Size	10,530	13.049	1.362	9.761	16.867
tfp	Firm total factor productivity	10,530	3.642	2.777	0.000	11.572
leverage	Asset-liability ratio	10,530	0.465	0.208	0.000	0.943
lnclratio	Asset density	10,530	5.805	1.309	2.574	9.343
cost	Firm transaction costs	10,530	0.098	0.073	0.000	0.411
innov	Firm autonomous innovation	10,530	0.526	0.215	0.156	0.923
lnimport	The value of imports of high-tech intermediate goods by firms	10,530	13.954	1.697	9.154	17.592

4.2. Variable Description

1. Dependent variable: Export technology complexity (lnESI)

Export technology complexity refers to the degree of technical sophistication embodied in exported products. It is an indicator used to reflect the technological level and export productivity of a country's exported goods [17,23]. Following the method of [23], we first calculate the export technology complexity at the product level, and then perform a weighted average based on the firm-level product export value. Finally, we obtain the firm-level export technology complexity and take its natural logarithm to eliminate heteroscedasticity.

2. Core explanatory variable: Export control variable (TSI):

The U.S. Entity List, established by the U.S. Bureau of Industry and Security (BIS) under the Export Administration Regulations (EAR), identifies foreign firms, organizations, and individuals deemed to have engaged in activities contrary to U.S. national security or foreign policy interests. Entities placed on the list are subject to stringent export control restrictions and face additional licensing requirements when accessing U.S.-origin goods, software, and technologies governed by the EAR.

The export control variable TSC_{it} captures whether a listed manufacturing firm was exposed to U.S. export controls through product-level trade linkages. If a listed manufacturing firm imported products associated with U.S. Entity List entries from or transited through the United States in year t , the variable is set to 1 for year t and all subsequent years, and 0 otherwise.

3. Control Variables

Control variables (X_{it}): (1) Firm age (age), we use the difference between the observation year and the firm's establishment year. (2) Firm size (lnsize), we use the logarithm of a company's main business revenue as a measure. (3) Total factor productivity (tfp), estimate using the OP method. (4) Leverage ratio (leverage), we use the ratio of a company's total liabilities to its total assets to express. (5) capital intensity (lnclratio), we obtain it by taking the logarithm of the ratio of net fixed assets to the average number of employees per year.

4. Mediating Variables

The mediating variables employed in this study include firms' transaction costs (cost), imports of high-technology intermediate goods (lnimport), and indigenous innovation capability (innov), which correspond respectively to the three underlying mechanisms of transaction cost escalation, supply chain disruption, and innovation chain disruption.

Firm transaction costs (cost) are measured as the ratio of the sum of selling expenses, administrative expenses, and financial expenses to operating revenue. This measure captures the overall operating and coordination costs borne by firms in production and market transactions.

Imports of high-technology intermediate goods ($\ln\text{import}$) are constructed in three steps. First, we identify five high-technology industries common to both the OECD high-technology product classification and the China High-Technology Industry Statistical Yearbook (2017), namely aircraft and spacecraft, office, accounting and computing machinery, radio, television and communication equipment, pharmaceuticals, and medical, precision and optical instruments. Second, we match SITC (Rev.3) codes to the UN BEC classification to isolate high-technology intermediates, then map these to HS2007 six-digit product codes. Finally, we aggregate firms' HS eight-digit import values from the Chinese Customs Trade Database to the HS six-digit level to compute total imports.

Indigenous innovation capability (innov) is measured by the proportion of in-house R&D expenditure relative to the combined total of R&D expenditure and technology acquisition expenditure. Technology acquisition expenditure is proxied by the amount spent on technology purchases disclosed under the "Intangible Assets" notes in listed firms' financial statements.

4.3. Empirical Strategy

To assess the impact of U.S. export controls on firms' export technology complexity, this paper uses firms' exposure to product-level trade activities associated with U.S. Entity List entries as a quasi-natural experiment and employs a multi-period difference-in-differences (DID) model for empirical analysis. Since different firms were added to or affected by the Entity List in different years, the staggered implementation of the policy provides suitable variation for identification. The baseline model is specified as follows:

$$\ln\text{ESI}_{it} = \alpha + \beta\text{TSI}_{it} + \gamma X_{it} + \mu_i + \lambda_t + \epsilon_{it} \quad (1)$$

In the model, $\ln\text{ESI}_{it}$ is the dependent variable, representing the logarithm of the firm i 's export technology complexity in year t . TSI_{it} is the core explanatory variable—a dummy variable indicating whether firm i was subject to export controls in year t . It is set to 1 if firm i was included in the U.S. Entity List or affected by such controls in year t , and 0 otherwise. X_{it} represents the set of control variables. μ_i and λ_t are the firm and year fixed effects, respectively, while ϵ_{it} is the random disturbance term.

5. Empirical Results

5.1. Baseline Regression Results

Table 2 reports the benchmark regression results. After controlling for year and firm individual fixed effects, the results in Column (1) show that the coefficient of U.S. export controls on China is significantly negative at the 1% significance level. Upon further inclusion of control variables such as firm age, size, and total factor productivity, the results in Column (2) indicate that the coefficient of the core explanatory variable is -0.0516 , and remains significantly negative at the 1% significance level. This finding indicates that U.S. export controls significantly impede improvements in the export technology complexity of Chinese manufacturing firms.

Table 2. Baseline regression results.

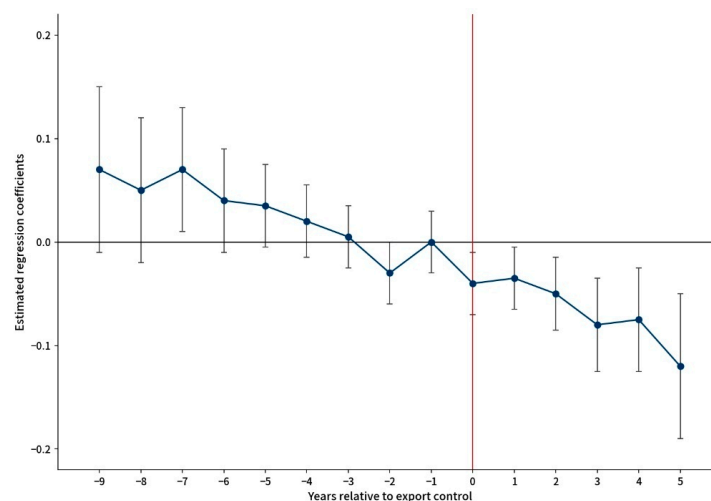
Variable	lnESI	
	(1)	(2)
TSI	−0.0521 *** (−3.35)	−0.0516 *** (−3.31)
age		−0.000 (−0.28)
lnsize		0.010 *** (3.05)
tfp		−0.000 (−0.41)
leverage		−0.017 (−1.07)
lnclratio		−0.000 (−0.03)
Year	YES	YES
Firm	YES	YES
Observations	10,530	10,530
R ²	0.726	0.726

Note: t statistics are in brackets; ***, **, and * indicate significance at the 1%, 5%, and 10% statistical levels, respectively.

5.2. Parallel Trend Test

A key prerequisite for conducting causal identification using the multi-time-point difference-in-differences method is the fulfillment of the “parallel trends” assumption, which stipulates that prior to the implementation of U.S. export controls, the export technology complexity of the treatment group (the regulated or affected firms) and the control group (the non-regulated or unaffected firms) should exhibit identical trends. To test this assumption, this section conducts a parallel trend test for further verification.

Figure 1 clearly demonstrates that before the implementation of export controls (periods -9 to -2), the 95% confidence intervals for the estimated policy effects all included zero. This indicates that prior to the impact of export controls, the trend in export technology complexity among firms in the treatment group showed no statistically significant difference from that of the control group, thereby satisfying the parallel trends assumption. During the period of the policy shock (period 0) and in subsequent periods (periods 1 to 5), the estimated dynamic treatment effects generally turned negative, with confidence intervals consistently excluding zero. This indicates that the decline in export technology complexity primarily emerged after exposure. These findings reduce concerns that the baseline result is driven by pre-existing trend differences.

**Figure 1.** Parallel trend test.

5.3. Robustness Checks

To ensure the robustness and reliability of the regression results, this paper conducts the following series of robustness tests:

5.3.1. Placebo Test

To verify the robustness of the baseline regression results and to rule out potential interference from unobservable factors or random shocks, this paper further conducts a placebo test by randomizing the core explanatory variable TSI. In each simulation, the values of TSI were randomly shuffled within the dataset, and the above randomization procedure was repeated 500 times to generate the kernel density distribution of the estimated coefficients.

Figure 2 shows that the kernel density curve of placebo coefficients is perfectly centered at 0 and follows a symmetric normal distribution. All 500 simulated coefficients cluster within $[-0.02, 0.02]$, while the true baseline coefficient (approximately -0.05) lies entirely in the left tail of the distribution. None of the 500 simulations yields a more negative coefficient ($p < 0.002$). This result indicates that the estimated negative effect is unlikely to be generated by random treatment assignment.

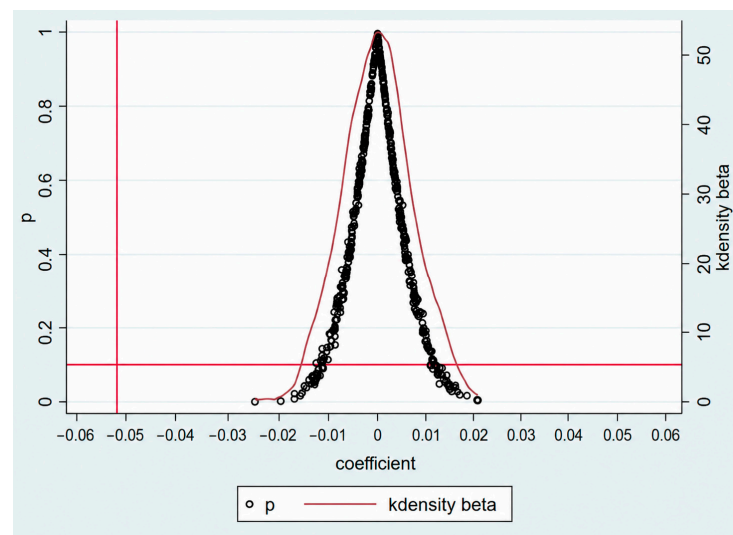


Figure 2. Placebo Test Result.

5.3.2. PSM-DID

Although the benchmark regression has controlled for year and firm fixed effects, the targets of U.S. export controls against China (i.e., the treatment group firms) were not randomly selected. When determining whether to add an entity to the Entity List, the U.S. government typically selects firms based on specific criteria, such as their technology complexity and the strategic importance of the industries in which they operate. This “selective bias” introduces systematic differences between treatment and control firms prior to policy implementation, potentially distorting the benchmark regression results. To mitigate the endogeneity problem arising from the non-random assignment of samples, this paper further employs the propensity score matching–difference-in-differences (PSM-DID) approach for robustness testing. This paper employs firm age, firm size, total factor productivity, capital intensity, and the asset-liability ratio as covariates, and applies one-to-one nearest-neighbor matching to perform propensity score matching for the treatment group samples. To verify the reliability of the matching results, this paper further tests whether the matched samples satisfy the balancing hypothesis. The results are presented

in Figure 3. In the figure, the dots (●) represent the standardized biases of each covariate before matching, while the crosses (×) represent the standardized biases after matching. The horizontal axis reports the percentage of standardized bias, and the vertical axis lists the names of the covariates.

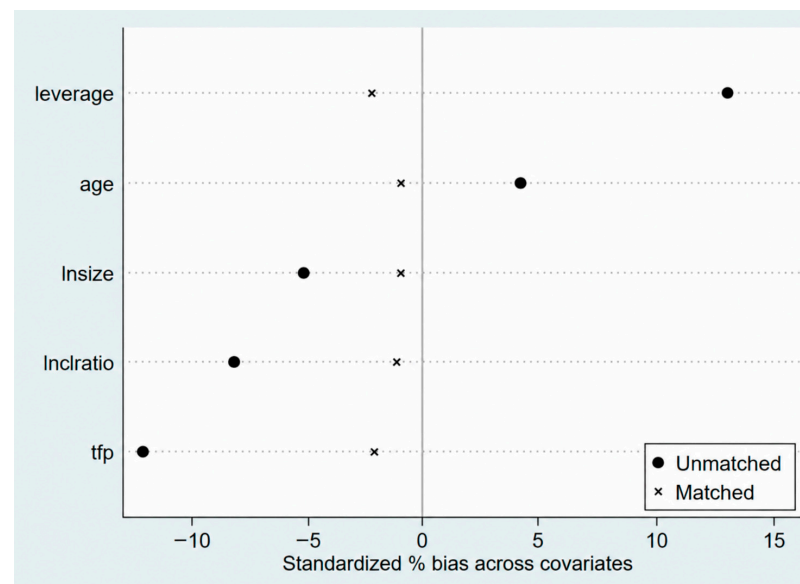


Figure 3. Balance Test.

Figure 3 shows that, after one-to-one nearest-neighbor matching, the standardized biases of all covariates converged substantially toward zero. The absolute values of the standardized biases for all variables were controlled within the acceptable threshold of 5%, with most covariates exhibiting biases close to zero. These findings suggest that the matching procedure effectively eliminated observable differences between the treatment and control groups, thereby improving the comparability of the two groups after matching. The balancing test is therefore satisfied, providing support for the subsequent application of the PSM-DID approach.

After preprocessing the samples using one-to-one nearest-neighbor propensity score matching (PSM), a multi-period difference-in-differences (DID) model was subsequently employed for the baseline regression analysis. The results are reported in Table 3. The results indicate that, after eliminating sample selection bias through propensity score matching, U.S. export controls against China continue to exert a significant negative effect on the export technology complexity of Chinese manufacturing firms, thereby further supporting the research hypothesis proposed in this paper. In addition, consistent conclusions are obtained when multi-period DID estimations are conducted following the application of radius matching and kernel matching methods to correct for sample bias.

Table 3. PSM-DID method results.

	lnESI	
TSI	−0.0420 *** (−2.78)	−0.0418 *** (−2.76)
age		−0.000 (−0.40)
Insize		0.010 *** (2.70)

Table 3. *Cont.*

lnESI		
tfp		−0.000 (−0.01)
leverage		−0.015 (−0.88)
lnclratio		−0.002 (−0.46)
Year	YES	YES
Firm	YES	YES
Observations	8876	8876
R ²	0.737	0.737

Note: t statistics are in brackets; ***, **, and * indicate significance at the 1%, 5%, and 10% statistical levels, respectively.

5.3.3. Add Control Variables

Considering that firms' profitability and cash flow conditions may affect their R&D investment and technological upgrading, thereby directly influencing export technology complexity, this paper further incorporates return on assets (ROA) and cash flow (CF) as additional control variables into the baseline model. The regression is then re-estimated to rule out the potential interference of firms' operating performance with the baseline results and to further verify the robustness of the core conclusions. The regression results are reported in Table 4. We find that the negative significance of the core explanatory variable remains unaffected after the inclusion of additional control variables, which further strengthens the credibility of the baseline regression results.

Table 4. Regression results after adding control variables.

lnESI			
TSI	−0.052 *** (−3.34)	−0.052 *** (−3.33)	−0.052 *** (−3.34)
ROA	−0.144 * (−1.67)		−0.128 (2.84)
CF		−0.060 (−1.23)	−0.033 (2.84)
Controls	YES	YES	YES
Year	YES	YES	YES
Firm	YES	YES	YES
Observations	10,530	10,530	10,530
R ²	0.726	0.726	0.726

Note: t statistics are in brackets; ***, **, and * indicate significance at the 1%, 5%, and 10% statistical levels, respectively.

5.3.4. Lagged Dependent Variable

To address potential issues of reverse causality among the variables, this paper re-estimates the model by lagging the dependent variable—export technology complexity (lnESI)—by one period (L.lnESI). As shown in Table 5, the coefficient of the core explanatory variable TSI remains significantly negative, further confirming the robustness of the main conclusions.

Table 5. One-period lagged regression results for the dependent variable.

	L.lnESI	
TSI	−0.040 *** (−2.70)	−0.039 *** (−2.66)
Controls	NO	YES
Firm	YES	YES
Year	YES	YES
Observations	9477	9477
R ²	0.735	0.726

Note: t statistics are in brackets; ***, **, and * indicate significance at the 1%, 5%, and 10% statistical levels, respectively.

5.3.5. Replacing the Measurement Method for the Dependent Variable

This study employs the [23] method to measure export technology complexity, an indicator closely linked to a country's income level. In the context of export controls, this indicator may be influenced by trade diversion effects. For instance, when a country faces export restrictions, its export share tends to decline. To examine the robustness of the conclusions, this paper recalculates firm-level export technology complexity ($\ln ESI_i^{HH}$) using the method proposed by [34]. We re-estimate the regression model using the natural logarithm of the Export Technology Complexity Index ($\ln ESI_i^{HH}$) as the dependent variable, and the results are reported in Table 6. The coefficient of the key explanatory variable remains statistically significant and negative, indicating that our findings are robust to the alternative measurement of the outcome variable.

Table 6. Regression results with different measurement methods for the dependent variable.

	$\ln ESI_i^{HH}$	
TSI	−0.049 *** (−2.81)	−0.049 *** (−2.78)
Controls	NO	YES
Firm	YES	YES
Year	YES	YES
Observations	10,530	10,530
R ²	0.237	0.237

Note: t statistics are in brackets; ***, **, and * indicate significance at the 1%, 5%, and 10% statistical levels, respectively.

5.3.6. Excluding the Impact of Other Policies and Events

The policy and event impacts excluded in this study specifically include: First, we exclude the impact of the 2008–2009 Global Financial Crisis. To eliminate the interference caused by this exceptional event, this paper removes the observations from 2008 to 2009 and re-estimates the regression model. The estimation results are presented in Column (1) of Table 7, we find that the results remain robust even after excluding the financial crisis impact. Second, we exclude the impact of the implementation of the Belt and Road Initiative in 2015. The official release of the “Vision and Actions on Jointly Building the Belt and Road” in 2015 marked the entry of the Belt and Road Initiative into its phase of comprehensive implementation. This adjustment in outward-oriented trade policy may have disrupted the export structure and the level of technological upgrading within the manufacturing sector. To eliminate the confounding effects of this policy shock, this study re-estimated the regression model after excluding the 2015 sample. As shown in Column (2) of Table 7, the results suggest that the main findings remain robust even after controlling for the impact of this policy, indicating that the conclusions are not significantly affected by the implementation of the Belt and Road Initiative.

Table 7. Regression results after excluding the impact of other policies and events.

	(1)	(2)
TSI	−0.041 *** (−3.62)	−0.053 *** (−4.59)
Controls	YES	YES
Firm	YES	YES
Year	YES	YES
Observations	8424	9477
R ²	0.732	0.736

Note: t statistics are in brackets; ***, **, and * indicate significance at the 1%, 5%, and 10% statistical levels, respectively.

5.4. Mechanism Test

Based on the theoretical analysis presented in the previous section, U.S. export controls on China may influence Chinese manufacturing firms' export technology complexity through three main mechanisms: increased transaction costs, supply chain disruptions, and innovation chain constraints. Accordingly, this section will test these theoretical mechanisms. Based on Equation (1), this section constructs the following model:

$$M_{it} = \alpha_1 + \beta_1 TSC_{it} + \gamma_1 X_{it} + \mu_i + \lambda_t + \epsilon_{it} \quad (2)$$

$$\ln ESI_{it} = \alpha_2 + \beta_2 TSC_{it} + \gamma_2 X_{it} + \mu_i + \lambda_t + \epsilon_{it} \quad (3)$$

where M_{it} represents three mediator variables: enterprise transaction costs ($cost_{it}$), the import value of high-tech intermediate goods ($\ln import_{it}$), and enterprise autonomous innovation ($innov_{it}$).

The regression results are presented in Table 8. First, here are the results of the test of the transaction cost mechanism. Column (1) presents the direct impact of export controls on transaction costs. The results show that U.S. export controls against China significantly increase corporate transaction costs. Column (2) indicates that an increase in transaction costs has a significant negative effect on export technology complexity. Taken together, these two results demonstrate that export controls inhibit the growth of export technical complexity by increasing firms' transaction costs. Secondly, the empirical results for the supply chain disruption mechanism are presented. Column (3) displays a significantly negative coefficient at the 1% level, indicating that U.S. export controls against China markedly reduce the import of high-tech intermediate goods by China's manufacturing firms. Column (4) suggests that the reduction in high-tech intermediate goods imports significantly inhibits the growth of export technology complexity. This further indicates that export controls suppress the increase in export technology complexity by disrupting the supply chains of manufacturing firms. Finally, column (5) shows that the coefficient is statistically significant at the 1% level and positive, indicating that U.S. export controls have a significant positive impact on firms' autonomous innovation. Column (6) further reveals that autonomous innovation significantly enhances the growth of export technology complexity. These findings suggest that U.S. export controls exert a positive effect on export technology complexity through the mechanism of supply chain disruption, which forces firms to strengthen their autonomous innovation capabilities.

Column (7) reports the joint regression incorporating all three mechanisms. The estimated effects, ranked from strongest to weakest, are the supply chain disruption mechanism, the innovation chain disruption mechanism, and the transaction cost mechanism. This indicates that supply chain disruption constitutes the primary transmission channel through which U.S. export controls suppress export technology complexity. Compared

with the other two channels, the mediating effect of the transaction cost mechanism is relatively limited, suggesting that it does not play a dominant role.

Table 8. Mechanism analysis.

	Transaction Cost		Supply Chain Disruption		Innovation Chain Breakdown		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	lncost	lnESI	lnimport	lnESI	innov	lnESI	lnESI
TSI	0.009 *** (2.84)	−0.051 *** (−3.26)	−0.199 *** (−3.77)	−0.034 ** (−2.22)	0.023 *** (2.69)	−0.054 *** (−3.45)	−0.036 ** (−2.31)
cost		−0.101 ** (−2.35)					−0.066 * (−1.67)
lnimport				0.087 *** (12.36)			0.086 *** (12.31)
innov						0.092 *** (7.34)	0.080 *** (6.85)
Controls	YES	YES	YES	YES	YES	YES	YES
Firm	YES	YES	YES	YES	YES	YES	YES
Year	YES	YES	YES	YES	YES	YES	YES
Observations	10,530	10,530	10,530	10,530	10,530	10,530	10,530
R ²	0.127	0.726	0.725	0.754	0.118	0.728	0.755

Note: t statistics are in brackets; ***, **, and * indicate significance at the 1%, 5%, and 10% statistical levels, respectively.

Moreover, the combined absolute magnitude of the negative effects exceeds that of the positive effects, implying that the overall impact remains negative. This finding suggests that although U.S. export controls may induce firms to strengthen indigenous innovation through innovation chain disruptions, the resulting positive effect is relatively limited and insufficient to offset the adverse impacts generated through the other two channels. Consequently, U.S. export controls overall continue to significantly inhibit the growth of China's manufacturing export technology complexity.

5.5. Heterogeneity Analysis

5.5.1. Heterogeneity of Enterprise Ownership

In the current landscape of export control policies, this paper finds that state-owned enterprises are more likely to become targets of export controls. Accordingly, we further introduce an ownership heterogeneity analysis to examine the differentiated impacts of export control measures across firms with different ownership structures. The regression results reported in Table 9 indicate that export controls exert a significantly negative effect primarily on the export technology complexity of state-owned enterprises.

Table 9. Heterogeneity analysis: enterprise ownership.

	(1) State-Owned Firms lnESI	(2) Non-State-Owned Firms lnESI
TSI	−0.067 ** (−2.23)	−0.037 (−1.28)
Controls	YES	YES
Firm	YES	YES
Year	YES	YES
Observations	4520	6010
R ²	0.732	0.681

Note: t statistics are in brackets; ***, **, and * indicate significance at the 1%, 5%, and 10% statistical levels, respectively.

This heterogeneous effect may stem from two main reasons. First, from the perspective of policy targeting, state-owned enterprises, as key pillars of national strategic technological

capabilities and critical industries, are more likely to be regarded by the United States as primary targets in technological competition and containment strategies. Consequently, they tend to face stricter restrictions in both Entity List designation and the implementation of export control measures. Second, from the perspective of firm characteristics, state-owned enterprises may exhibit greater rigidity in their technological trajectories, supply chain configurations, and international cooperation networks. When access to critical U.S. technologies is disrupted, their capacity for adjustment and substitution tends to be relatively limited, thereby amplifying the adverse effects of export controls. By contrast, non-state-owned enterprises generally operate under more market-oriented and diversified business models and may possess greater flexibility in seeking alternative technology sources on a global scale, which enables them to demonstrate a certain degree of resilience against such shocks.

The findings of this section suggest that the effects of U.S. export controls are not homogeneous, but instead exhibit significant ownership-based heterogeneity, with state-owned enterprises bearing the primary policy shock. This implies that, when assessing the macroeconomic consequences of U.S. export controls on China and formulating corresponding policy responses, it is essential to account for the structural differences at the micro-firm level. In particular, greater attention and policy support should be directed toward state-owned enterprises in order to safeguard the security and stability of China's industrial and supply chains.

5.5.2. Regional Heterogeneity

China's regional economic development is characterized by pronounced imbalance, with substantial differences across the eastern, central, and western regions in terms of industrial structure, factor endowments, and the degree of openness to the outside world. These disparities provide firms with distinct external environments and constraints when responding to external shocks. The eastern region is deeply embedded in global value chains, with a high concentration of export-oriented firms and advanced manufacturing industries, resulting in a stronger dependence on international technology supply chains. Consequently, U.S. export controls are likely to exert a more direct and severe impact on firms located in the eastern region. By contrast, the industrial systems in the central and western regions are relatively more inward-oriented and more closely connected to domestic industrial chains. This implies that the direct transmission of shocks from global supply chain disruptions may be comparatively weaker, though still far from negligible.

To examine the regional heterogeneity effects of the impact of U.S. export control policies, this study further divides the entire sample into three sub-samples, namely, eastern, central, and western regions, based on the provinces where the enterprises are located, and conducts regressions separately. Table 10 presents the corresponding regression results. The eastern region includes Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan. The central region includes Shanxi, Jilin, Heilongjiang, Henan, Hubei, Hunan, Anhui, and Jiangxi. The western region includes Inner Mongolia, Chongqing, Sichuan, Guangxi, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang.

As shown in Table 10, export controls exert a significantly negative effect on the export technology complexity of firms located in the eastern region. In contrast, the effects on firms in the central and western regions are statistically insignificant. This finding clearly reveals the regional heterogeneity effects of the shocks generated by U.S. export controls and provides an important basis for formulating differentiated regional policy responses. For the eastern region, which experiences the most severe impact, policy efforts should focus on stabilizing high-end supply chains and supporting breakthroughs in frontier

technologies. For the central and western regions, policymakers should adopt a forward-looking approach by accelerating industrial upgrading and strengthening the development of a domestically oriented technological circulation system.

Table 10. Heterogeneous analysis by region.

	(1) Central lnESI	(2) Eastern lnESI	(3) Western lnESI
TSI	−0.053 (−1.26)	−0.074 ** (−2.24)	−0.020 (−0.56)
Controls	YES	YES	YES
Firm	YES	YES	YES
Year	YES	YES	YES
Observations	3380	3760	3390
R ²	0.651	0.731	0.744

Note: t statistics are in brackets; ***, **, and * indicate significance at the 1%, 5%, and 10% statistical levels, respectively.

5.5.3. Industry Heterogeneity

This paper categorizes the national economy into 35 industries according to the industry classification in the WIOD (NACE), with manufacturing classified as C3 to C16. Furthermore, based on the OECD's classification of industrial R&D intensity and the actual development of China's manufacturing sector, manufacturing is divided into three major categories: low-tech, medium-tech, and high-tech manufacturing. We then examine whether the effects of U.S. export controls on enterprises' export technology complexity vary across low-tech, medium-tech, and high-tech manufacturing industries. The results are reported in Table 11.

Table 11. Heterogeneous analysis by industry.

	(1) High-Tech Industry lnESI	(2) Medium-Tech Industry lnESI	(3) Low-Tech Industry lnESI
TSI	−0.065 ** (−2.10)	−0.055 (−1.10)	−0.035 (−1.13)
Controls	YES	YES	YES
Firm	YES	YES	YES
Year	YES	YES	YES
Observations	4200	2820	3510
R ²	0.684	0.653	0.764

Note: t statistics are in brackets; ***, **, and * indicate significance at the 1%, 5%, and 10% statistical levels, respectively.

The results of the industry heterogeneity analysis indicate that the inhibitory effect of U.S. export controls on the export technology complexity of China's manufacturing sector exhibits significant differences across industries. Specifically, the coefficient of TSI in the high-technology manufacturing subsample is −0.065 and is statistically significant at the 5% level, whereas the coefficients in the medium- and low-technology manufacturing subsamples are negative but statistically insignificant, with their absolute magnitudes decreasing sequentially. This result is consistent with the underlying logic of U.S. export control policies, namely, to hinder China's industrial upgrading and technological progress by restricting access to core technologies and high-end manufacturing sectors.

5.5.4. Heterogeneity in Enterprise Size

Compared with small and medium-sized enterprises, large leading firms, owing to their greater strategic importance and stronger technological influence, are more likely to

become the primary targets of export control measures. Consequently, the suppressive effect on their export technology complexity may also be more pronounced. Accordingly, this paper divides manufacturing firms into large enterprises and small- and medium-sized enterprises based on the median value of total assets and conducts an empirical analysis, with results presented in Table 12.

Table 12. Heterogeneity analysis: enterprise size.

	(1) Large Firms lnESI	(2) Medium and Small Firms lnESI
TSI	−0.061 ** (−2.54)	−0.030 (−0.73)
Controls	YES	YES
Firm	YES	YES
Year	YES	YES
Observations	7230	3300
R ²	0.699	0.708

Note: t statistics are in brackets; ***, **, and * indicate significance at the 1%, 5%, and 10% statistical levels, respectively.

The heterogeneity analysis by firm size indicates that the inhibitory effect of U.S. export controls on the export technology complexity of China's manufacturing firms differs significantly across firm size categories. Specifically, the coefficient of TSI in the large-enterprise subsample is −0.061 and statistically significant at the 5% level, whereas the coefficient in the small- and medium-sized enterprise subsample is −0.030 and statistically insignificant. These findings suggest that U.S. export controls exert a substantially stronger negative impact on the export technology complexity of large manufacturing firms, while their effects on small- and medium-sized enterprises are relatively limited.

6. Conclusions and Recommendations

6.1. Conclusions

Against the backdrop of intensifying Sino-U.S. technological rivalry, U.S. export controls targeting high-technology industries have become a pivotal policy instrument reshaping global value chains and technological trajectories, presenting formidable challenges to the export upgrading of China's manufacturing sector. This paper investigates the impact of U.S. export controls on the technology complexity of China's manufacturing exports using data on Chinese manufacturing firms, the U.S. Entity List, and the China Customs Data. The main conclusions are as follows:

First, U.S. export controls significantly inhibit the growth of China's manufacturing export technology complexity. Empirical results based on a multi-period DID model show that firms subject to export controls experience a substantial decline in export technology complexity relative to control group firms. This conclusion remains robust after a series of robustness and endogeneity tests.

Second, mechanism analysis reveals that U.S. export controls affect manufacturing export technology complexity through three major channels. Specifically, export controls suppress technology complexity by disrupting supply chains and increasing transaction costs, while innovation-chain disruptions may simultaneously induce firms to strengthen indigenous innovation. However, the negative effects generated through supply chain disruptions and transaction costs outweigh the positive effects associated with innovation substitution, leading to an overall inhibitory impact. Among the three channels, supply chain disruption constitutes the dominant transmission mechanism, whereas the mediating effect of transaction costs is comparatively limited.

Third, heterogeneity analysis finds that the effects of U.S. export controls vary significantly across different types of firms. The inhibitory effect is particularly pronounced among state-owned enterprises, firms located in eastern regions, large enterprises, and high-technology manufacturing industries. These findings highlight the structural heterogeneity of export control shocks and provide important implications for differentiated policy responses aimed at enhancing industrial resilience and safeguarding supply-chain security.

6.2. Policy Recommendations

The findings of this study suggest several important policy implications. First, the findings suggest that strengthening support for indigenous innovation and promoting breakthroughs in core technologies may help reduce external technological dependence and enhance the resilience of manufacturing upgrading under export-control pressures. In particular, high-technology industries and strategically important firms may warrant greater policy attention because they appear to be more vulnerable to export-control restrictions.

Second, given that supply-chain disruption emerges as the primary transmission mechanism in our empirical analysis, improving the resilience and stability of industrial and supply chains may represent an effective policy direction. Measures such as diversifying technology sources and export markets, strengthening domestic capabilities in key intermediate inputs, and enhancing coordination within domestic industrial chains may help mitigate firms' exposure to external supply-chain disruptions.

Third, the heterogeneity results suggest that policy responses may need to account for differences in firm characteristics and regional conditions. More targeted support may be considered for state-owned enterprises, large firms, and enterprises located in eastern regions, which appear to be more strongly affected by export-control shocks. At the same time, policies that encourage technological upgrading and deeper participation in domestic innovation networks among medium- and small-sized enterprises, as well as firms in central and western regions, may contribute to strengthening the overall resilience of China's manufacturing sector to external technological restrictions.

Owing to data availability constraints in the China Customs Data, our analysis is limited to the 2006–2015 period. Future research could extend the analysis using post-2017 data to examine whether the mechanisms identified in this study remain operative under a more intensive export-control regime or whether new transmission channels emerge.

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Abbreviations

The following abbreviations are used in this manuscript:

R&D	Research and Development
ESG	Environmental, Social and Governance
CSMAR	China Stock Market & Accounting Research Database

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