Technical Regulations and Export Quality: Evidence from Supply Chains in China

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Abstract: *As global trade networks deepen and trade patterns evolve, supply chain dynamics have emerged as a critical driver of high-quality development—particularly as reflected in firms' capacity to export higher-quality products. Drawing on new-new trade theory, this study incorporates supply chain behavior—specifically, the use of intermediate goods—into the analytical framework for determining export product quality. Theoretically, it posits that technical regulations on the supply chain influence export quality through two key channels: improvements in the quality of intermediate inputs and changes in their associated costs. Empirically, the study exploits China's imposition of technical barriers to trade (TBT) on intermediate goods imports as a quasi-natural experiment, applying a difference-in-differences approach to firm-level export data from 2000 to 2014. The results show that supply chain technical regulations lead to significant improvements in the quality of exported final products. Mechanistically, the regulations raise the quality of imported intermediates, which in turn drive upgrades in final outputs, while leaving import costs largely unchanged—since compliance expenses are absorbed by foreign exporters rather than passed on to Chinese firms. Further analysis reveals substantial heterogeneity in these effects, depending on both the type of regulation and firm characteristics. These variations reflect differences in regulatory intensity and in firms' sensitivity to supply chain changes, adaptability, and capacity to convert input quality into product upgrades. Overall, the findings suggest that strengthening supply-side regulatory standards—when properly designed—represents a strategic lever for improving product quality and enhancing firms' international competitiveness, offering valuable insights for trade policy and global supply chain governance.*

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1. Introduction

In an era of intensifying global market competition, product quality has become a central pillar for firms striving to gain a competitive edge internationally. Supplying high-quality products not only helps companies establish a strong market reputation and enhance brand value but also ensures long-term, stable revenue. More importantly, it strengthens a firm's core competitiveness, enabling it to expand

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into global markets and seize broader development opportunities. For enterprises aiming to "go global", the quality of their export products is a decisive factor for success.At the same time, supply chains have taken on greater importance in today's globalized economic environment. Beyond simply linking production and consumption, supply chains underpin a company's survival and growth. Their resilience and security are now vital; disruptions can prevent firms from adapting swiftly to market fluctuations or even lead to production halts. China's central leadership has repeatedly emphasized the need to enhance the resilience and security of industrial and supply chains. Maintaining robust supply chains has thus become a critical factor for enterprises, with this goal directly linked to achieving high-quality development—as reflected particularly in the export of superior products. Against this backdrop, this paper examines whether technical regulations targeting upstream supply chains—referred to as *supply chain technical regulations*—influence the quality of final product exports by domestic firms. Adopting the perspective of intermediate goods imports, the study investigates whether imposing stricter technical requirements on inputs from upstream suppliers affects export quality. In doing so, it seeks to identify general patterns in firms' export behavior in response to supply chain shocks. The findings offer valuable insights for understanding supply chain risks and supporting enterprises in achieving high-quality, sustainable development.

Building on the *new-new trade theory*, this study incorporates the level of intermediate input use into the theoretical framework for determining firms' export product quality. Mathematical derivations reveal that supply chain technical regulations exert two opposing forces: on one hand, they increase the cost of intermediate inputs; on the other, they improve the quality of these inputs. Both channels significantly affect the quality of final products, but in opposite directions. Consequently, existing literature has yet to reach a clear conclusion on how technical regulations ultimately influence export product quality when the supply chain is impacted. Empirically, a major challenge arises from the strong endogeneity between firms' supply chain decisions and output behavior. Firms often adjust their upstream activities in response to final product requirements, making it difficult to disentangle the net causal effect of supply chain changes on export quality. Addressing this endogeneity remains a central difficulty in current research.To overcome this challenge, our study exploits a quasi-natural experiment: China's imposition of TBT on intermediate goods imports. TBT serve as a representative form of supply chain technical regulation for two key reasons. First, intermediate goods supplied by foreign producers are essential components of domestic firms' upstream supply chains, making import behavior a clear reflection of supply chain dynamics (Chen et al., 2023; Peng & Li, 2024). Second, by definition, TBT impose more stringent technical standards on imported goods—covering areas such as health, safety, and environmental protection—through legally binding regulations, procedures, and standards (Singh & Chanda, 2020). The World Trade Organization classifies TBT under its *Technical Regulation Article*, further reinforcing their relevance to this study's focus.

This TBT framework provides a compelling quasi-natural experiment to examine the effect of technical regulations on product quality. It enables us to address the endogeneity stemming from the interdependence between supply chain activity and production outcomes. To conduct this analysis, we leverage three major datasets: the China Customs Database, the China Industrial Enterprise Database, and the WTO TBT Database. We apply a DID approach to rigorously estimate the impact of supply chain technical regulations on the quality of exported products.The results are revealing: overall, supply chain technical regulations tend to enhance the quality of firms' final product exports. This effect operates through two main mechanisms. First, technical regulations lead to higher-quality intermediate inputs, which directly improve the quality of the final products. Second—and contrary to conventional assumptions—these regulations do not pass through to the cost of intermediate imports for domestic firms. This is due to the information disclosure effect of TBT, which expands the volume of intermediate goods imports, strengthens the bargaining power of domestic firms, and shifts the burden of compliance costs onto foreign suppliers.

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This study offers significant marginal contributions, primarily in three areas: First, research perspective. This paper introduces a novel perspective by examining the impact of supply chain shocks through the lens of technical regulations. It explores the general patterns by which supply chain technical regulations influence the quality of firms' exported products. This enriches and expands the "input-output" research frontier from an international trade perspective. Second, theoretical framework. Building on the frameworks of Khandelwal et al. (2013) and Fan et al. (2015), this study constructs an equilibrium model that incorporates supply chain shocks, specifically intermediate goods trade. Integrating the new-new trade theory, it systematically delineates the complete causal pathway through which supply chain technical regulations affect enterprise export product quality. Third, research methodology. Leveraging China's implementation of TBT on intermediate goods imports as a quasi-natural experiment, this study identifies the net effect of supply chain technical regulations on enterprise export product quality. By comparing the behavior of affected and unaffected firms, this approach effectively mitigates the endogeneity issues arising from the strong reverse causality between supply chain participation and output decisions.

2. Literature Review

This study engages with three key strands of literature relevant to the analysis of supply chain shocks and export product quality: (1) research on supply chains, (2) the role of intermediate goods imports, and (3) determinants of export product quality.

Supply Chain Research: Supply chains, as critical components of production networks, influence input-output fluctuations across sectors (Acemoglu et al., 2017). At the firm level, extensive research underscores the transmission mechanisms linking upstream and downstream enterprises. For example, supply chains facilitate the propagation of bottom-up effects such as horizontal merger waves (Li et al., 2023) and risk contagion (Gao et al., 2023), highlighting the interdependence of firm behavior within the supply network. A prominent focus of the literature is how external shocks—such as natural disasters or human-induced disruptions—affect supply chain operations. These shocks can significantly disrupt coordination efficiency, increase linkage costs, and exacerbate risk transmission across sectors (Barrot & Julien, 2016; Boehm et al., 2019; Carvalho et al., 2021). In addition to unexpected events, economic policy changes also serve as important sources of supply chain shocks. Cai et al. (2023), for instance, examine the effects of tax reduction policies and find that downstream tax relief fosters supply chain data sharing, thereby enhancing midstream firm performance. As digital technologies and artificial intelligence continue to evolve, recent studies have increasingly emphasized the role of digitalization and intelligent systems in mitigating supply chain risks. A growing consensus suggests that digital adoption by upstream and downstream firms generates positive spillover effects through supply chain transmission (Wu & Yao, 2023; Tao et al., 2023).

Intermediate Goods Imports: Given this paper's focus on supply chain shocks from the perspective of intermediate goods imports, the second strand of literature centers on the economic impacts of such imports. Intermediate goods imports are shown to expand firms' production scope (Goldberg et al., 2010), enhance the quality of exported products (Xu et al., 2017), and serve as conduits for knowledge and technology transfer, thus boosting total factor productivity (TFP) (Colantone & Crinò, 2014). Using data from China, Zhang et al. (2015) find that these productivity gains are primarily transmitted through price mechanisms, particularly in industries with low export dependency. A significant portion of the literature also explores the liberalization of intermediate goods trade, especially through tariff reductions, and its effects on firm-level outcomes such as export intensity, employment, and technological complexity (Tian & Yu, 2013; Mao & Xu, 2016; Sheng & Mao, 2017). Non-tariff barriers (NTBs), particularly TBT, have also gained scholarly attention. Tian et al. (2023) demonstrate that TBT applied to intermediate goods imports can improve the TFP of domestic processing trade firms, primarily through

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improvements in product quality and production scale. Similarly, Chen et al. (2023) treat China's anti-dumping actions on intermediate goods as a quasi-natural experiment and find that such shocks prompt firms to streamline their product portfolios and focus on core offerings.

Export Product Quality**:** The third strand of literature examines the determinants of export product quality, which can be broadly categorized into internal capabilities and external environments. On the internal side, production capacity—encompassing quality control, production efficiency, and equipment maintenance—plays a vital role in shaping export quality (Bastos & Silva, 2010; Johnson, 2012). Technological innovation is one of the most important means of improving export product quality (Shi & Shao, 2014). It enhances production efficiency, reduces costs, and increases the likelihood that firms will develop high-quality products with proprietary intellectual property rights (Zhu & Tang, 2020). Externally, market demand conditions, trade environments, and policy shocks influence quality decisions. Demand-side factors such as the wealth and income distribution of importing countries are critical determinants (Crinò & Epifani, 2010; Bekkers et al., 2012). On the trade environment side, geographic proximity, the degree of trade liberalization, and exchange rate fluctuations also shape export quality outcomes (Fan et al., 2022; Xu et al., 2015). From a policy perspective, quality-related regulations—including TBT—directly affect export quality (Hu et al., 2019), while changes in export tax rates driven by anti-dumping measures can have indirect effects (Moraga-González & Viaene, 2015).

While existing research provides rich insights into the economic functions of supply chains and the determinants of export product quality, studies examining the link between supply chain shocks and export quality remain scarce—especially from the standpoint of technical regulations. Furthermore, empirical analyses often face methodological challenges in addressing endogeneity stemming from reverse causality between supply chain structure and firm performance. To address these gaps, this study adopts an equilibrium framework grounded in new-new trade theory to analytically derive the effects of technical regulations on intermediate goods imports and their influence on export product quality. It further employs China's TBT measures on intermediate goods as a quasi-natural experiment to empirically test these effects. This dual approach strengthens causal inference, mitigates endogeneity concerns, and offers novel insights into how technical regulations reshape global trade patterns through supply chain dynamics.

3. Theoretical Mechanism

This study builds a mathematical model based on the frameworks of Khandelwal et al. (2013) and Fan et al. (2015), incorporating factors such as intermediate input prices and quality to endogenize export product quality. The model examines the impact of supply chain technical regulations on the export product quality of affected firms and their underlying channels under equilibrium conditions of consumer utility maximization and firm profit maximization.

3.1 Consumer Behavior

We assume that the utility of consumers in the importing country hinges on the quantity and quality of consumed products, with the elasticity of substitution between products represented by a fixed value $\sigma(\sigma>1)$. The consumer's CES utility function is expressed as:

$$U=\left[\int_{k\in\Omega}\left(q_k x_k\right)^{\frac{\sigma-1}{\sigma}}\mathrm{d}k\right]^{\frac{\sigma}{\sigma-1}} \tag{1}$$

where subscript k denotes the product, U represents total utility, q_k indicates product quality, and x_k signifies consumption quantity. By applying the first-order condition of the utility function in equation (1), we derive the optimal consumption quantity that maximizes consumer utility:

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$$x_k = \frac{p_k^{-\sigma} Y}{P^{1-\sigma} q_k^{1-\sigma}} \tag{2}$$

In this equation, p_k is the product price, Y represents the importing country's total expenditure (calculated as $Y \equiv \int_{k\in\Omega} (x_k p_k)\,dk$), and P is the composite price index of the importing country (computed as $P \equiv \left[\int_{k\in\Omega} (p_k/q_k)^{1-\sigma} dk\right]^{\frac{1}{1-\sigma}}$).

3.2 Producer Behavior

The scale of product production is generally determined by factor inputs. For simplicity, we assume that a firm's final product production relies solely on labor and intermediate goods, with constant returns to scale between inputs and outputs. The production function is thus expressed as:

$$F(L, M) = \varphi L^{1-\mu} M^{\mu} \tag{3}$$

where $1-\mu$ and μ denote the output elasticities of labor and intermediate goods, respectively; φ represents productivity; L is the labor input level; and M is the intermediate input level. Analogous to the utility function, the intermediate input level depends on both the quantity of intermediate inputs (c_m)—endogenously determined by factors like import prices—and the quality of intermediate inputs (ψ_m), which is exogenously determined by supplier-related factors outside the model[1]. Based on this, the production function in equation (3) can be further specified as:

$$F(L, c_m, \psi_m) = \varphi L^{1-\mu} (c_m \psi_m)^{\mu} \tag{4}$$

To simplify the model, labor price (wage level) is normalized to 1. Since optimal input quantities of labor and intermediate goods depend on factor prices, the marginal cost mc_k^c of producing and exporting product k is derived as:

$$mc_k^c = \frac{\kappa q_k^{\beta} P_m^{\mu}}{\varphi \psi_m^{\mu}} \tag{5}$$

where $\kappa=\mu^{-\mu}(1-\mu)^{\mu-1}$ is a constant, β is the quality elasticity of variable costs ($\beta<1$), reflecting the change in variable costs due to improved export product quality, and p_m is the intermediate input price. Following Fan et al. (2022), the total intermediate input quantity (C_m) required for production is aggregated from a basket of intermediate goods, expressed as:

$$C_m = \Lambda \exp\left[\int_0^{+\infty} a(z) \ln c(z) dz\right] \tag{6}$$

where $\Lambda = \exp\left[\int_0^{+\infty} a(z) \ln a(z) dz\right]$, $a(z)$ represents the input share, satisfying $\int_0^{+\infty} a(z)dz=1$; and $c(z)$ is the quality-adjusted quantity of input z. The intermediate input price is then derived as:

$$P_m = \exp\left[\int_0^{+\infty} a(z) \ln p(z) dz\right] \tag{7}$$

Here, $p(z)$ is the firm's quality-adjusted input cost. If a firm sources intermediate goods through both foreign imports and domestic purchases, the cost of importing is $\tau p^f(z)$, where $p^f(z)$ is the domestic price from the exporter's perspective, and τ captures iceberg trade costs (e.g., transportation, customs clearance, and quarantine). The price of domestically sourced intermediate goods is $p^d(z)$. Firms choose

[1] This assumption aligns with existing studies (Zhu et al., 2018) and matches the mechanism of technical regulation shocks, as domestically imposed technical regulations are exogenous to firms (detailed later), and their impact on imported input quality can be treated as an exogenous shock.

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the lower-cost option, satisfying $p(z)=\min\left\{\tau p^f(z),\ p^d(z)\right\}$. Following existing research, we assume a critical point z* where domestic and foreign prices are equal. Foreign suppliers typically have a comparative advantage for products below z*, while domestic producers dominate for products above z* (Dornbusch et al., 1977). Thus, firms import when z<z* and purchase domestically when z>z*. The total intermediate input price is then:

$$P_m=\exp\left[\int_0^{z^*}a(z)\ln(\tau p^f(z))dz+\int_{z^*}^{+\infty}a(z)\ln(p^d(z))dz\right] \tag{8}$$

Taking the partial derivative of equation (8) shows that $\partial P_m/\partial\tau>0$, i.e., P_m is positively correlated with iceberg costs[2]. Similarly, as intermediate input quality is exogenously determined, the quality of composite intermediate inputs is expressed as:

$$\psi_m=\exp\left[\int_0^{z^*}a(z)\ln(\phi(z))dz+\int_{z^*}^{+\infty}a(z)\ln(\eta(z))dz\right] \tag{9}$$

where $\phi(z)$ is the standardized quality of imported intermediate goods z, and $\eta(z)$ is the standardized quality of domestically purchased intermediate goods z. Beyond marginal production costs, exporting firms incur fixed costs to sustain production, operations, and trade, expressed as:

$$F_k=fq_k^{a}+F_0 \tag{10}$$

where F_k denotes total fixed costs, α is the quality elasticity of fixed costs (reflecting cost changes due to improved export quality), and f represents other production cost parameters, $f>0$, with F_0 indicating fixed costs incurred in production or exporting. The firm's total profit is then:

$$\pi_k=p_kx_k-mc_kx_k-F_k \tag{11}$$

Substituting the optimal consumer utility condition from equation (2) into the above yields:

$$\pi_k=\left(p_k-\frac{\kappa q_k^{\beta}P_m^{\mu}}{\varphi\psi_m^{\mu}}\right)\frac{p_k^{-\sigma}Y}{P^{1-\sigma}q_k^{1-\sigma}}-fq_k^{\alpha}-F_0 \tag{12}$$

Applying the first-order condition ($\partial\pi_k/\partial p_k=0$) to maximize profit, we derive the firm's optimal pricing:

$$p_k=\frac{\sigma}{\sigma-1}\left(\frac{\kappa q_k^{\beta}P_m^{\mu}}{\varphi\psi_m^{\mu}}\right) \tag{13}$$

Substituting this back into equation (12) provides the firm's profit performance:

$$\pi_k=(\sigma\text{-}1)^{\sigma\text{-}1}\sigma^{-\sigma}\left(\frac{\varphi\psi_m^{\mu}q_k^{1-\beta}P}{\kappa P_m^{\mu}}\right)^{\sigma-1}Y-fq_k^{\alpha}-F_0 \tag{14}$$

3.3 Determinants of Enterprise Export Product Quality

Based on the profit function in equation (14) and the corresponding first-order condition ($\partial\pi_k/\partial q_k=0$), we derive the following equation:

$$(\sigma\text{-}1)^{\sigma}\sigma^{-\sigma}(1-\beta)q_k^{-1}\left(\frac{\varphi\psi_m^{\mu}q_k^{1-\beta}P}{\kappa P_m^{\mu}}\right)^{\sigma-1}Y-\alpha fq_k^{\alpha-1}=0 \tag{15}$$

[2] When considering a scenario in which some or all intermediate goods are imported from foreign markets, the analysis yields consistent conclusions. If a firm sources all of its intermediate inputs through imports, the cost of acquiring these goods can be represented as $\tau p^f(z)$, and the total cost of intermediate input usage can be expressed as $P_m=\exp\left[\int_0^{+\infty}a(z)\ln(\tau p^f(z))dz\right]$. In this case, the total cost of intermediate inputs is positively correlated with the iceberg cost. The same reasoning applies to conclusions regarding the quality of intermediate inputs.

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By simplifying and generalizing equation (15), we obtain the endogenous determinant of export product quality under equilibrium conditions:

$$q_k = \left[\frac{(\sigma\text{-}1)^{\sigma}(1-\beta)}{\alpha\sigma^{\sigma}} \kappa^{1-\sigma} P_m^{\mu(1-\sigma)} \psi_m^{\mu(\sigma-1)} \varphi^{\sigma-1} f^{-1} P^{\sigma-1} Y \right]^{\frac{1}{\alpha-(\sigma-1)(1-\beta)}} \tag{16}$$

This determinant shows that export product quality is influenced by a range of factors. This study focuses on those affected by technical regulations—namely, the quality and cost of intermediate inputs. It is important to emphasize that, under real-world conditions, the firm's profit function is convergent. That is, improvements in product quality do not lead to unbounded profit growth; we define $\alpha-(\sigma-1)(1-\beta)>0$ accordingly. Under this assumption, taking the partial derivatives of export product quality with respect to intermediate input quality and cost from equation (16) yields: $\partial q_k/\partial \psi_m>0$; $\partial q_k/\partial P_m<0$. Combined with equations (8) and (9), we further derive: $\partial q_k/\partial \phi(z)>0$; $\partial q_k/\partial \tau p^f(z)<0$. These results consistently demonstrate that the quality of a firm's exported final products is positively related to the quality of its intermediate inputs and negatively related to the cost of those inputs. This conclusion is supported by both theoretical reasoning and empirical evidence. As essential production factors, intermediate inputs are incorporated into final goods, and the technologies embedded within them play a decisive role in determining output quality (Goldberg et al., 2010). Therefore, improvements in the quality of intermediate inputs directly promote higher final product quality. On the other hand, rising intermediate input costs not only reduce firms' flexibility in adjusting input combinations, making quality enhancements more difficult, but also divert resources toward procurement. This reallocation diminishes overall efficiency in both resource distribution and operational performance, ultimately constraining the ability to produce high-quality outputs. Hence, the following lemma can be derived:

Lemma 1: Firm export product quality increases with the quality of intermediate inputs and decreases with their cost.

3.4 Impact of Supply Chain Technical Regulations on Firm Export Product Quality

Supply chain technical regulations implemented by importing countries affect the quality of final product exports by influencing both the quality and cost of intermediate inputs. On one hand, such regulations typically impose higher standards on supply chain products in terms of technology, performance, and quality. These standards are often embedded in product R&D and design, compelling suppliers or intermediate input exporters to enhance their product quality in order to meet export requirements. As a result, firms that continue exporting under these regulations improve the quality of their intermediate inputs $\phi(z)$ (Hu et al., 2019). Beyond this mandatory and passive compliance, technical regulations also lead to greater information disclosure. This allows other suppliers to better understand importers' requirements and align their products with the regulatory standards. By reducing information asymmetry between suppliers and importers, technical regulations intensify quality competition through the disclosure effect. In response, intermediate input exporters proactively improve product quality to maintain competitiveness. Following the specification approach of Shen & Yuan (2020), we model the relationship between intermediate input quality and the degree of technical regulation (TR) as:

$$\phi(z)=\phi_0 e(TR),\quad TR>0,\quad \phi_0>0,\quad e'(\cdot)>0 \tag{17}$$

where ϕ_0 denotes the firm's initial intermediate input quality—that is, the exogenously determined level of quality in the absence of technical regulation. $e(TR)$ is a function of TR and $e'(\cdot)>0$ satisfies the condition that intermediate input quality increases with the level of technical regulation, i.e., $\partial\phi(z)/\partial TR>0$. On the other hand, from the perspective of intermediate input suppliers, technical regulations raise production costs. To comply with the new standards, suppliers must invest in technical equipment and skilled labor. They also incur inspection-related expenses, such as for product reviews and customs

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clearance. As such, technical regulations can be viewed as cost-increasing trade barriers. Foreign suppliers must bear these "compliance costs" to satisfy the technical requirements imposed by importing countries. These *TR*-incurred compliance costs are modeled as an increase in the iceberg trade cost τ. Following previous specifications, the relationship is expressed as:

$$\tau=\tau_0\lambda(TR),\ TR>0,\ \tau_0>0,\ \lambda'(\cdot)>0 \tag{18}$$

where τ_0 denotes the initial iceberg cost of intermediate inputs in the absence of technical regulation, and $\lambda(TR)$ is a function of TR, and $\lambda'(\cdot)>0$ capture the compliance cost effect, i.e., $\partial\tau/\partial TR>0$. Combining this with intermediate input prices, we obtain $\partial\tau p^f(z)/\partial TR>0$, indicating that technical regulations increase the cost of intermediate inputs. The underlying economic logic is as follows: technical regulations raise exporters' marginal production costs, leading to higher export prices. For domestic firms importing intermediate inputs, this implies increased input costs. In summary, we derive:

Lemma 2: Technical regulations imposed by importing countries on the supply chain increase the quality of intermediate inputs for domestic firms but also raise the cost of those inputs.

Building on Lemma 1 and incorporating Lemma 2, we establish the full causal pathway linking export product quality q_k to supply chain technical regulations (*TR*): $\partial q_k/\partial\phi(z)\cdot\partial\phi(z)/\partial TR>0$; $\partial q_k/\partial\tau p^f(z)\cdot\partial\tau p^f(z)/\partial TR<0$. This framework clarifies the channels and mechanisms through which technical regulations influence export quality. Hence, we propose:

Theoretical Hypothesis: Supply chain technical regulations exert both an *input quality effect* and an *input cost effect*. That is, they enhance the quality of final export products by improving the quality of intermediate inputs, while at the same time reducing final export quality by increasing the cost of these inputs.

According to this hypothesis, the overall effect of technical regulations on export product quality depends on the relative strength of the two channels. If the positive input quality effect dominates, the net effect will be positive—indicating a quality-enhancing outcome. Conversely, if the negative input cost effect prevails, the overall impact will be detrimental to product quality.

4. Research Design

4.1 Data Selection

(1) Supply chain technical regulations: This study uses China's restrictive TBT targeting intermediate goods as a quasi-natural experiment to examine supply chain technical regulations. TBT imposed on imported intermediate inputs are considered a typical form of supply chain technical regulation. However, it is important to note that such regulations do not necessarily hinder trade for all partner countries. In some cases, products from certain supplying countries may already meet the required technical standards *before* the imposition of the regulation. Under such circumstances, domestic firms importing from these countries may not experience any disruption, and their supply chains may remain unaffected by the TBT. Therefore, not all TBT constitute substantive technical regulations. To address this, we follow the widely adopted approach in existing literature by focusing on those TBT that have triggered *STCs* in WTO discussions (e.g., Fontagné & Orefice, 2018; Singh & Chanda, 2020; Wang & Ma, 2022). This approach allows us to identify which TBT are genuinely restrictive. Specifically, the WTO's TBT Committee provides a platform for member states to negotiate and discuss particular TBT measures. If a member state believes a TBT imposed by another country significantly restricts its exports, it may raise an STC through the committee. Given the limited number of committee meetings, only highly restrictive TBT are likely to trigger STCs.Thus, the STC dataset offers a unique advantage over other non-tariff measure (NTM) databases, as it systematically identifies TBT with true trade-restrictive effects. The STC database spans from 1995 to 2011 and includes the following information: the concern-raising and maintaining members, the date the concern was raised, any follow-up discussions, the HS

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4-digit product codes involved, the stated objectives of the TBT, and the specific concerns raised by concern-raising members.

(2) Firm-level behavior: Firm-level data used in this study are drawn from a merged dataset combining Chinese customs data and the Annual Survey of Industrial Firms (ASIF). The customs data track detailed information on every trade transaction by Chinese foreign trade enterprises. For our purposes, we focus on key variables such as product HS codes for imports and exports, export destination countries, intermediate input source countries, trade values, and quantities. The ASIF provides information on the operations and structure of China's state-owned and above-scale non-state-owned enterprises. This includes key variables such as year of establishment, employment size, output value, profit, and debt levels.

(3) Matching procedure: First, following standard practice in the literature, we identify intermediate inputs based on the BEC product classification system. Products classified under BEC codes 111, 121, 21, 22, 31, 322, 42, and 53 are treated as intermediate goods. Using the WTO's conversion table, we match these BEC codes to HS codes, allowing us to extract firms engaged in importing intermediate inputs from the customs data. We then aggregate the import data to the HS 4-digit level by year (while export data remain at the HS 8-digit level). Second, we match this processed customs data with the ASIF using identifiers such as year, company name, contact information, and postal code, thereby incorporating firm characteristics into our dataset. Third, we match the merged dataset with the WTO STC data based on year, product HS code, and intermediate input source country. Firms whose intermediate input imports correspond to TBT identified as STCs are considered to have been affected by restrictive technical regulations. This allows us to incorporate TBT shocks into the dataset. Finally, we aggregate all indicators at the firm level, identifying firms whose supply chains were impacted by technical regulations and the timing of such impacts. We exclude observations with missing values for key variables required for subsequent analyses. The resulting balanced panel covers the period from 2000 to 2014.

(4) Stylized facts. The final dataset reveals the following stylized facts: First, from 2000 to 2014, the number of restricted intermediate products and affected firms due to China's implementation of restrictive TBT steadily increased. By the end of the sample period, over 570 intermediate goods and more than 4,300 firms had been affected by supply chain-related technical regulations, indicating the broad scope of such policies. Second, kernel density analysis of export product quality for treated vs. untreated firms shows that firms affected by supply chain technical regulations experienced a noticeable improvement in export product quality post-shock. This confirms the presence of a measurable quality effect stemming from such regulations and provides a solid empirical foundation and motivation for the subsequent identification strategy, analysis of underlying mechanisms, and exploration of heterogeneity.

4.2 Model Selection

To fulfill the research objectives, this paper adopts a multi-period difference-in-differences (DID) model to examine the impact of supply chain technical regulations on the quality of firms' export products. This methodological choice is based on two main considerations. First, the DID model enables precise causal inference by treating the introduction of trade barriers as a policy shock. In this study, China's imposition of TBT on imported intermediate goods serves as a quasi-natural experiment. The DID approach allows for the identification of the "net effect" of supply chain technical regulations on export product quality, thus supporting robust estimation of causal relationships. Second, the DID model effectively captures the prolonged impact of TBT. These regulations, once enacted, often persist for a significant period. Even if they lose their restrictive nature or are no longer flagged as specific trade concerns (STCs), the investments in equipment, technology, and skilled labor made by intermediate input suppliers in response to earlier regulations continue to shape their export behavior over time. This creates a lasting, inertial effect on the quality of final products that incorporate these inputs. The

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DID model's approach to estimating average effects over sustained periods aligns seamlessly with this dynamic, making it an ideal tool for our analysis[3].

To ensure the validity of DID estimates, a critical assumption is that the treatment—the imposition of TBT—is exogenous to the affected firms. This assumption holds true in the context of this study. TBT are implemented at the product level rather than the firm level. That is, importing countries apply TBT to specific products and do so uniformly across all exporting countries. Due to the diverse and complex sourcing patterns of intermediate inputs among firms, and the variation in TBT restrictiveness across different trading partners, whether a firm is affected by a given TBT depends solely on the origin of its imported inputs. As such, the assignment of treatment can be considered random within the sample. Additionally, the policy motivations behind TBT, as documented by the WTO, are generally unrelated to the export behavior of firms. TBT are often introduced for reasons such as protecting consumer safety, ensuring environmental standards, or supporting domestic industries. These objectives are not linked to the specific export decisions or strategies of firms. Therefore, the possibility of reverse causality or other forms of non-random interference is minimal in this setting.

4.3 Model Design

To investigate the effect of supply chain technical regulations on the export product quality of affected firms, this study utilizes China's implementation of technical barriers to trade (TBT) on intermediate goods imports as a quasi-natural experiment. Employing a DID framework, an econometric model is constructed for empirical analysis:

$$Q_{ft}=a+\beta Treat_f\times T_{ft}+\lambda X_{ft}+\varphi_t+\varphi_f+\varepsilon_{ft} \tag{19}$$

In this model, the subscripts f and t denote firms and years, respectively. The dependent variable Q_{ft} represents the quality of export products. The core explanatory variable $Treat_f\times T_{ft}$ captures whether a firm's supply chain is affected by technical regulations, with its coefficient estimating the treatment effect of TBT on intermediate goods imports. Control variables X_{ft} are included to account for firm-specific characteristics. Firm φ_f and year φ_t fixed effects control for unobserved heterogeneity across firms and over time, while the random error term ε_{ft} ensures model robustness.

4.4 Variable Measurement

(1) The core explanatory variable $Treat_f\times T_{ft}$, indicating whether the supply chain is affected by technical regulations, is constructed in two parts. The first part $Treat_f$ involves classifying firms into treatment and control groups. Firms whose intermediate goods imports involve products subject to STCs—and are therefore influenced by restrictive TBT—are included in the treatment group, assigned a value of 1, i.e., $Treat_f$=1. All other exporting firms are assigned to the control group, with a value of 0, i.e., $Treat_f$=0. The second part T_{ft} defines a time dummy variable based on the timing of the STC. If a firm-year observation falls in or after the year in which the STC was raised, it is considered affected and coded as 1; otherwise, it is coded as 0. For firms that experience multiple TBT shocks during the sample period, only the first instance is used, following established empirical practice. The interaction between the group assignment and the time dummy $Treat_f\times T_{ft}$ forms the core explanatory variable in the DID model.

(2) The dependent variable, export product quality (Q_{ft}), is measured using the residual value method, a widely accepted approach in existing literature. This method infers product quality from observed prices and quantities, measured by:

[3] Given that the DID model compares the average differences in outcomes before and after policy intervention, it is particularly appropriate for evaluating such long-term effects. Moreover, since the WTO does not provide information on whether specific STCs are eventually resolved, using DID instead of a standard OLS model also helps to mitigate potential measurement errors.

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$$\ln(x_{fjkt})=\sigma\ln(p_{fjkt})+\phi_k+\phi_{jt}+\varepsilon_{fjkt} \quad (20)$$

Subscripts j and k represent the destination country and export product, respectively. x_{fjkt} denotes the export volume at the firm-product-destination country level, while p_{fjkt} represents the corresponding export price. ϕ_k captures product fixed effects, and ϕ_{jt} reflects destination country-year fixed effects. The residual term, ε_{ijkt}, represents unobserved export product quality and is interpreted as $q_{fjkt}=\varepsilon_{ijkt}$. To facilitate the analysis of heterogeneous products within a unified framework, this study follows a widely adopted approach in the existing literature, i.e., $\bar{q}_{fjkt}=\frac{q_{fjkt}-\min q_{fjkt}}{\max q_{fjkt}-\min q_{fjkt}}$. Specifically, using the method proposed by Shi et al. (2013), export product quality is standardized based on the maximum and minimum values observed for each firm's exported products. The standardized quality for each product-destination combination is then aggregated to the firm level by weighting according to the share of export value at that level in the firm's total exports. This produces the final measure of firm-level export product quality, which is suitable for use in regression analysis. The weighting formula is given by: $Q_{ft}=\sum\frac{x_{fjkt}}{\sum_{fjkt\in\Omega}x_{fjkt}}\times\bar{q}_{fjkt}$.

(3) Control variables are introduced to reflect firm size and operational status. These include the number of employees ($Staff_{ft}$), total assets ($Assert_{ft}$), firm age (Age_{ft}), profitability (Roa_{ft}), and the debt ratio ($Lever_{ft}$). To minimize the influence of outliers, the number of employees, total assets, profitability, and debt ratio are winsorized at the top and bottom 0.5 percent. Balance tests indicate that the treatment and control groups are comparable in terms of the mean values of these variables, suggesting that the parallel trends assumption necessary for the DID framework is reasonably satisfied.

5. Empirical Results

5.1 Baseline Regression

Baseline regression results are presented in Table 1. In column (1), the coefficient of the core explanatory variable is significantly positive, indicating that technical regulations imposed on the supply chain effectively enhance the quality of firms' exported final products. Column (2) includes a set of Control variables, and the coefficient of the core explanatory variable remains significantly positive at the 1% level. Based on the results reported in this column, it can be inferred that China's supply chain-related technical regulations, on average, improve firms' export product quality by 0.003 standard deviations. This finding suggests that the positive impact of improved intermediate input quality outweighs the potential negative impact of increased export costs resulting from such regulations.

Table 1: Baseline Regression Results

Variables	(1)	(2)
	Q_{ift}	Q_{ift}
$Treat_f\times T_{ft}$	0.003***	0.003***
	(0.001)	(0.001)
Control variables	No	Yes
Year fixed effects	Yes	Yes
Firm fixed effects	Yes	Yes
R^2	0.720	0.729
N	723665	633174

*Note: ***, *, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors are clustered at the province level (same below).

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5.2 Validity Tests for the DID Model

(1) Parallel trend test. The validity of the DID estimation relies on the assumption that the treatment and control groups followed parallel trends in the outcome variable prior to the policy shock. To verify this, we examine the dynamic trajectory of export product quality before and after the imposition of technical regulations. The results show no significant differences between the two groups prior to the shock, confirming that the parallel trend condition is satisfied. This supports the validity of the DID approach used in this study.

(2) Placebo test. The placebo test checks whether the selection of the control group is appropriate. Specifically, we randomly sample firms from the original control group (those not subject to TBT shocks) to create a pseudo-treatment group of the same size as the actual treatment group. The remaining firms are treated as the control group. If the original grouping is valid, the estimated treatment effects should be statistically insignificant. We repeat this process 500 times using the Bootstrap method and plot the results using kernel density estimation. The estimated coefficients are consistently centered around zero, indicating the absence of spurious treatment effects. This confirms the robustness of our control group selection.

(3) Negative weight test. This study employs a two-way fixed effects DID model across multiple periods. However, as noted by Goodman-Bacon (2021), such models can be biased due to the presence of negative weights in the weighted average of standard DID estimators when treatment effects vary over time. If the share of negative weights is substantial, the DID estimator may be distorted. Following De Chaisemartin & D'Haultfoeuille (2020), we decompose the weights and find that positive weights sum to 1.08, while negative weights total -0.08. This indicates that negative weighting is limited and does not pose a substantial risk of estimation bias in our results.

(4) Spillover effect test. The DID model assumes no interference between treatment and control groups. However, in reality, firms within the same region or industry may be interconnected through information sharing or market linkages. If technical regulations affect some firms' product quality, neighboring or related firms may also experience quality changes due to industrial agglomeration or trade spillovers. In such cases, the control group could be indirectly affected, violating the DID assumption of independence and biasing the estimated treatment effect. To assess this, we follow the method of Lu et al. (2019) to test for potential spillover effects across regions and industries. The results show that such spillovers are statistically insignificant.

5.3 Additional Robustness Checks

We conduct a series of robustness tests to confirm the robustness of our baseline findings. These include: (i) redefining the core explanatory variable; (ii) using alternative measures of the dependent variable; (iii) adjusting the scope of the control group; (iv) changing the clustering level; (v) excluding processing trade firms; (vi) applying PSM-DID estimation; (vii) modifying sample selection criteria; and (viii) accounting for lagged effects. All robustness checks yield results consistent with the baseline regression, supporting the reliability of the findings.

6. Mechanism Testing

According to the theoretical framework, supply chain technical regulations affect the quality of firms' exported products through two main channels: improvements in the quality of intermediate inputs and increases in the cost of those inputs. Baseline regression results suggest that the quality-improvement channel has a relatively stronger effect. However, these theoretical mechanisms require further empirical verification. Therefore, this section conducts a mechanism analysis to supplement and explain the baseline findings.

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6.1 Intermediate Input Quality Channel

As outlined in the theoretical section, the improvement in input quality due to supply chain technical regulations primarily stems from higher quality in imported intermediate goods. To clarify this mechanism, we apply the residual value method to estimate the quality of imported intermediates at three levels: the firm-product-destination country level, the firm-product level, and the firm level. Based on these estimates, we then assess the impact of supply chain technical regulations on the quality of imported intermediate inputs. The results are presented in columns (1) to (3) of Table 2. In all specifications, the treatment effect coefficients are significantly positive, indicating that supply chain technical regulations significantly enhance the quality of imported intermediate goods. Furthermore, these results remain robust across all levels of quality measurement. We then examine the relationship between intermediate input quality and final product export quality. As shown in column (4) of Table 2, the coefficient for intermediate input quality is significantly positive. Moreover, the magnitude of the treatment effect of technical regulations decreases substantially relative to the baseline regression. This suggests that the observed improvement in final product quality is, at least in part, driven by the enhanced quality of intermediate goods induced by technical regulations. These empirical findings are consistent with theoretical expectations. China's technical regulations targeting the supply chain compel upstream suppliers of intermediate goods to improve their product quality to meet new compliance standards. Since imported intermediate goods often embody advanced foreign production technologies and frontier R&D capabilities, their integration into the production processes of domestic firms contributes to an upgrade in the quality of final exported products. These results provide empirical support for the existence of the intermediate input quality channel.

Table 2: Mechanism Testing - Intermediate Input Quality Channel

Variable	(1)	(2)	(3)	(4)
	Q_{fpct}^{im}	Q_{fpt}^{im}	Q_{ft}^{im}	Q_{ft}
$Treat_f \times T_{ft}$	0.015*** (0.001)	0.047*** (0.002)	0.007*** (0.001)	0.006*** (0.002)
Q_{ft}^{im}				0.093*** (0.009)
Control variables	Controlled	Controlled	Controlled	Controlled
Year fixed effects	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
Product fixed effects	Yes	Yes	No	No
Destination country fixed effects	Yes	No	No	No
R^2	0.235	0.349	0.701	0.724
N	5574348	1750537	230655	205147

6.2 Intermediate Input Cost Channel

The price of input factors is the most direct reflection of a firm's input costs. The theoretical framework suggests that rising input costs are primarily driven by increases in the import prices of intermediate goods. To test this hypothesis, we examine the impact of supply chain technical regulations on the import prices of intermediate goods. Following a similar approach to the measurement of export product quality, we standardize import prices to facilitate comparisons across different product categories. The results are presented in column (1) of Table 3. We find no significant relationship between technical regulations and import prices, suggesting that China's TBT on intermediate goods do not increase the prices of these goods when exported to China. This finding is inconsistent with theoretical expectations. To further investigate, we plot the kernel density of intermediate goods import

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prices before and after the regulatory shock. The distributions show no marked divergence, indicating that prices remained largely stable before and after the shock—further supporting our empirical findings. If technical regulations do not lead to higher prices, the implication is that the associated compliance costs are absorbed by exporters of intermediate goods. This indicates a case of exporter cost absorption. We argue that such a phenomenon is more likely for intermediate goods that are technologically simple and easily substitutable. Under these conditions, importers gain stronger bargaining power—especially when the import volume expands—thus weakening the exporters' ability to pass on compliance costs through price increases.

To test this mechanism, we next examine the impact of technical regulations on the scale of intermediate goods imports. As shown in column (2) of Table 3, China's TBT significantly increase the import volume of intermediate goods. This is consistent with the findings of Tian et al. (2023), and can be explained from two perspectives:

Information disclosure effect: TBT often mandate standards that protect domestic health, safety, and legitimate rights. These standards provide more detailed product information, reducing information costs and asymmetry for importing firms (Schmidt & Steingress, 2022), thereby facilitating trade in intermediate goods.

Demand promotion effect: As previously discussed, technical regulations can improve the quality of imported intermediate goods. Higher-quality imports are more attractive to downstream firms and may serve as substitutes for similar domestic inputs. The assurance of quality and safety provided by TBT can stimulate demand (Ganslandt & Markusen, 2001; Bao & Qiu, 2012), thus increasing the volume of imported intermediates.

To further confirm whether price absorption is primarily driven by expanded import volumes, we augment the model in column (1) by adding import volume and an interaction term between TBT treatment and import volume. The results are presented in column (3) of Table 3. After accounting for import scale, the previously insignificant treatment effect becomes significantly positive at the 1% level. This implies that, absent the scale effect, technical regulations would indeed have raised import prices—affirming the existence of compliance costs. Moreover, the interaction term's negative coefficient indicates that increased import scale significantly suppresses import prices for intermediate goods. Taken together, the results in columns (1) through (3) provide a comprehensive explanation: China's supply chain technical regulations—via improved information disclosure and quality enhancement—lead to an increase in the import volume of affected intermediate goods. The expansion in import volume enhances importers' bargaining power. Combined with the low technological complexity and high substitutability of these goods, compliance costs are ultimately borne and absorbed by exporters. As a result, these costs are not reflected in higher prices, and thus do not increase domestic firms' intermediate input costs.

Table 3: Mechanism Testing - Intermediate Input Cost Channel

Variables	(1)	(2)	(3)
	p^{im}_{fpct}	$Value^{im}_{fpt}$	p^{im}_{fpct}
$Treat_f \times T_{ft}$	-0.000 (0.000)	0.131*** (0.028)	0.002*** (0.000)
$Value^{im}_{fpt}$			0.001*** (0.000)
$Value^{im}_{fpt} \times Treat_f \times T_{ft}$			-0.000*** (0.000)
Control variables	Controlled	Controlled	Controlled
Year fixed effects	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes

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Table 3 Continued

Variables	(1)	(2)	(3)
	p^{im}_{fpct}	$Value^{im}_{fpt}$	p^{im}_{fpct}
Product fixed effects	Yes	Yes	Yes
Destination country fixed effects	Yes	Yes	Yes
R^2	0.150	0.293	0.154
N	9986518	10617981	9986518

6.3 Other Corroborating Evidence

If the proposed mechanism—high input quality coupled with low input costs—holds, it should not only lead to an upgrade in export product quality but also improve other indicators of export performance. A common manifestation of this is an increase in the variety of finished products exported by firms. Introducing relatively higher-quality production inputs at lower costs can expand a firm's product scope and export boundaries (Goldberg et al., 2010; Colantone & Crinò, 2014). Based on this reasoning, we further assess the validity of our mechanism by testing whether supply chain technical regulations also influence other export performance metrics through the same channels. The results indicate that these regulations indeed lead to increases in both the variety of export products and the diversification of export markets. These findings align with the expectations derived from the proposed mechanism and provide additional corroborating evidence.

7. Heterogeneity Analysis

Existing research suggests that supply chain technical regulations generally have a positive effect on the quality of export products. However, these regulations are not homogeneous: some are related to trade protectionism, others to product quality or safety. Only through a clear classification of these regulations can we identify the underlying mechanisms via heterogeneous effects. Moreover, the impact of such regulations may vary across firms due to heterogeneity in capabilities and adjustment strategies. Different firms respond differently to supply chain disruptions depending on their sensitivity to regulation and the magnitude of the necessary adjustments, leading to variation in final product quality outcomes. To address this, we conduct subgroup heterogeneity analyses based on both regulation types and firm characteristics, providing empirical and theoretical foundations for differentiated trade policy development.

7.1 Technical Regulation Heterogeneity

The TBT database provides detailed classifications of regulation targets. In this study, we categorize six key categories of technical barriers—"quality requirements", "national security", "environmental protection", "health protection", "consumer protection", and "prevention of deceptive practices"—into three broader groups: Product Quality for "quality requirements"; Product Safety for "national security", "environmental protection", and "health protection"; and Protectionism for "consumer protection" and "prevention of deceptive practices". We create dummy variables $Category_{ft}$ for each category (1 if a regulation falls into that category, 0 otherwise) and incorporate them into the previously used DID model. A triple difference (DDD) approach is then employed to estimate the differential impacts of each regulation type on export product quality.

Results Summary (Table 4): Column (1): The interaction term for Product Quality × Treatment is significantly positive, indicating that technical regulations targeting product quality have a strong positive effect on export product quality. Column (2): The Protectionism × Treatment term is significantly negative, suggesting a weaker effect compared to other categories. Column (3): The Product Safety

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× Treatment term is statistically insignificant, indicating no significant deviation from the average effect of other regulatory categories. These findings, together with baseline and mechanism regression results, reinforce the proposed mechanism. The preceding section has shown that supply chain technical regulations primarily affect finished product quality through improvements in input quality, while the input cost channel has limited influence due to cost absorption. Technical regulations targeting "Product Quality" directly enhance input quality, leading to a stronger overall impact, which is consistent with the conclusions drawn from this paper's classified empirical analysis. Regulations aimed at "Protectionism" primarily seek to protect domestic interests and prevent deceptive practices, relying more on cost-based restrictions with a weaker constraint on input quality compared to both "Product Quality" and "Product Safety" requirements, resulting in a lesser overall effect on finished product quality. Although "Product Safety" regulations exert a clear regulatory effect on input quality—stronger than "Protectionism" but less direct than "Product Quality" requirements—their overall effect remains moderate, explaining the lack of statistical significance in the interaction term.

Table 4: Heterogeneity Analysis - Technical Regulation Categories

Variable	Product quality	Protectionism	Product safety
	(1)	(2)	(3)
	Q_{fi}	Q_{fi}	Q_{fi}
$Treat_f \times T_{ft} \times Category_{ft}$	0.005*** (0.002)	-0.006** (0.003)	-0.001 (0.001)
$Treat_f \times T_{ft}$	0.002*** (0.001)	0.003*** (0.001)	0.004*** (0.001)
Control variables	Controlled	Controlled	Controlled
Year fixed effects	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes
R^2	0.729	0.729	0.729
N	633174	633174	633174

7.2 Firm Heterogeneity

(1) Firms with different input resilience: Firms are categorized based on whether the affected intermediate goods are sourced exclusively from STC-initiating countries (low input resilience) or also include non-initiating countries (high input resilience). Regression results show that supply chain technical regulations have a greater effect on the export product quality of firms sourcing solely from initiating countries. A possible explanation lies in the differing roles and responses of firms and their suppliers:

- For firms with diversified sourcing (high resilience): These firms can adjust their supply chain strategies, such as reallocating imports from non-initiating countries, to mitigate short-term import restrictions caused by technical regulations.
- For firms with limited sourcing options (low resilience): These firms face a greater shock to their intermediate inputs. This creates an incentive for their suppliers to comply with technical regulations, driving a larger increase in input quality. Additionally, the concentration of import orders from these firms strengthens their bargaining power, enabling them to secure lower input costs.

Consequently, the combined effect of enhanced input quality from supplier compliance and reduced input costs due to stronger bargaining power results in a more significant quality improvement from technical regulations for low-resilience firms.

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(2) Firms with different output resilience**:** From the perspective of output resilience, we classify firms into single-product and multi-product categories for heterogeneity analysis. The regression results show that supply chain technical regulations have a greater impact on the export product quality of single-product firms (or firms with lower trade resilience) than on multi-product firms (or firms with higher trade resilience). This difference likely stems from the structural characteristics of these firms.

Single-product firms: These firms operate with a single output channel, meaning all imported intermediate goods are dedicated to the production of one product. As a result, they exhibit lower overall trade resilience. When the supply chain is disrupted, the resulting pressure and incentive to adjust are both greater. Moreover, this concentrated production model increases the firm's capacity to absorb supply chain changes. Under such conditions, improvements in input quality brought about by external shocks are more completely transmitted to the quality of the final product.

Multi-product firms: These firms have a more diversified product portfolio. Even if technical regulations affect the supply chain for certain products, the production and export of other products can continue unaffected. Therefore, the overall impact on multi-product firms is generally less significant compared to that on single-product firms.

(3) Firms with different innovation capabilities: We categorize firms into high-innovation-vitality and low-innovation-vitality groups based on whether they have developed new products (i.e., whether the value of new product output for that year is zero). The regression results indicate that supply chain technical regulations have a greater positive effect on the export product quality of high-innovation-vitality firms compared to their low-innovation-vitality counterparts. This variation is due to differences in adaptability and absorptive capacity:

High-innovation-vitality firms: These firms are more capable of adapting to and absorbing the significant improvements in intermediate goods quality brought about by technical regulations. They also demonstrate a stronger ability to embed this higher input quality into their production processes, resulting in improved final product quality. This reflects their capacity to establish an effective linkage and positive feedback loop between high-quality inputs and outputs.

Low-innovation-vitality firms: These firms often struggle to seize the opportunities arising from input quality improvements. Due to certain frictional costs, some efficiency is lost in the transition from input quality to output quality, limiting their capacity to enhance the quality of their final products.

8. Conclusions and Policy Implications

Anchored in the new-new trade theory, this paper incorporates intermediate inputs into the analytical framework for determining export product quality, examining how supply chain technical regulations affect this quality and through which channels. It leverages China's technical barriers to imports of intermediate goods as a quasi-natural experiment, applying a DID methodology and drawing on a comprehensive dataset that merges micro-level data from the 2000-2014 China Industrial Enterprise Database, the China Customs Database, and the WTO's TBT/IMS database.

The study yields several key findings:

(1) On the whole, supply chain technical regulations lead to an improvement in the quality of firms' exported final products.

(2) The mechanism driving this improvement operates on two levels. First, technical regulations enhance the quality of imported intermediate inputs, which in turn cascades into higher quality final products. Second, these regulations do not raise firms' import costs. Rather, the information disclosure effect triggered by such regulations increases the volume of intermediate goods imports, enhances domestic firms' bargaining power, and shifts compliance costs onto foreign exporters.

(3) Heterogeneity analysis reveals that the effect of technical regulations on export quality varies depending on the type of regulation and firm characteristics. This variation reflects differences in

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regulatory effectiveness and in firms' sensitivity to supply chain dynamics, flexibility in response, and capacity to translate higher input quality into improved outputs.

These findings carry several policy implications. Improvements in supply-side quality are embedded within finished products, driving both product quality upgrades and broader enhancements in export performance—thus contributing to firm development. To support high-quality growth, it is essential to strengthen supply-side management.

Domestically, this means establishing robust supply-side management systems encompassing end-to-end quality control—from raw material procurement to packaging and distribution—ensuring that each stage adheres to rigorous standards. Enterprises should also enhance supplier oversight to guarantee alignment in quality and process standards, and build comprehensive input quality testing systems, including raw material inspections and in-process sampling.

Externally, encouraging technological innovation and collaboration across upstream and downstream firms can foster coordinated improvements in production. Deepening engagement with international production networks will further diversify supply sources, enhancing resilience and adaptability in times of disruption or when upgrading supply chains.

Finally, given that TBT are a major form of non-tariff measures, their dual role is especially significant for China. As the world's largest exporter and a major importer, China frequently faces a range of TBT. At the same time, maintaining appropriate import standards is essential for safeguarding national interests and supporting domestic industries. This study finds that clearly defined standards for imports can actually stimulate import growth—an outcome that aligns with China's strategic goal of expanding imports. Moreover, moderately raising standards for intermediate goods can catalyze improvements in the quality of final export products.

This study also finds that moderately raising import standards for intermediate goods can generate positive spillovers, leading to improvements in the quality of final products. To harness this effect, several policy directions are recommended: First, China should make strategic use of the information disclosure effect associated with TBT. By actively releasing import standard information through multilateral platforms such as the WTO, China can reduce information asymmetry in key product markets, thereby expanding imports of critical and scarce goods. Second, it is essential to calibrate the stringency of technical regulations applied to imports. Chinese regulatory agencies and enterprises must enhance their capacity to monitor developments in global markets and foreign technological standards. Leveraging the technological sophistication and competitiveness of Chinese industries, relevant authorities should establish a robust compliance assessment and certification framework to ensure that imported intermediate goods meet stringent quality standards under technical regulations. Third, while aiming to foster a virtuous cycle of high-quality inputs and outputs, it is crucial to mitigate the risk of supply chain disruptions caused by regulatory interventions. To this end, China should take the lead in developing a globally harmonized set of supply chain technical standards, ensuring compatibility in upstream technologies and standardizing their application. At the same time, strengthening technical oversight and conducting systematic risk assessments across supply chains will be key to identifying and resolving potential vulnerabilities, thus ensuring long-term supply chain resilience and security.

Finally, this study finds that the marginal effects of technical regulations on export product quality differ across firm types. Nevertheless, the overall potential for quality improvement remains significant. To strengthen firms' ability to consistently produce and export high-quality products, the following policy actions are recommended: First, government authorities should enhance supervision and management of export product quality. This includes establishing a comprehensive traceability system that records and transmits information across all stages of the supply chain—such as production, processing, transportation, and sales—to ensure that quality information is transparent, traceable, and readily accessible. Second, firms should be encouraged and supported to invest in technological innovation, which is the key driver of export quality improvement. By increasing R&D investment and

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adopting advanced technologies, enterprises can upgrade the technical complexity and added value of their products, thereby boosting their competitiveness in international markets. Third, policymakers and industry stakeholders should work to deepen international cooperation and exchange. Building partnerships with international organizations and foreign enterprises can help co-develop and refine quality standards and regulatory systems. This includes collaboration on quality risk assessment, safety monitoring, and public disclosure of quality information. Such efforts will enhance the coordination and resilience of global production networks and improve their ability to manage risks related to export product quality.

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