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Adoption of International Standards and the Stability of Cross-Border Supply Chain Relationships: Firm-Level
Evidence from China

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Abstract

Cross-border production is sustained by durable buyer-supplier ties, yet research on standards has focused mainly on trade volumes, market access, and product quality rather than on the survival of the relationships through which production is organized. Using data for Chinese listed manufacturers over 2010-2024, we combine FactSet Revere customer-supplier links, CSMAR firm data, and an industry-year measure of the adoption of international standards. We construct a normalized annual termination rate from the observed start and end dates of foreign customer and supplier relationships. Firm and year fixed-effects estimates show that greater adoption of international standards is associated with significantly lower relationship termination. A one-standard-deviation increase in Std corresponds to a 0.0456 decline in Break, about 13.4% of its sample mean. The finding is robust to an instrumental-variable strategy based on industry exposure to ISO technical committees and subcommittees, alternative codings of standard adoption and relationship termination, and sample restrictions. Mechanism tests indicate that greater standard adoption is associated with a larger Merton distance-to-default, consistent with improved credit quality and lower counterparty risk. The stabilizing effect is strongest in less technology-intensive manufacturing, in lower-uncertainty environments, and among firms with less asset-specific capital. These results shift the economics of standardization from market access toward the durability of the cross-border production relationships through which global trade is organized.

Keywords: international standards; buyer-supplier relationships; relationship termination; global supply chains; firm-level trade

JEL classification: F14; F23; L14; L15

1 Introduction

Global production is organized through repeated relationships between firms rather than through anonymous spot transactions alone. Finding a suitable foreign customer or supplier requires search, screening, technical qualification, and repeated coordination. Once a match is formed, the parties accumulate knowledge about product specifications, quality control, delivery routines, and each other's reliability. These relationship-specific assets create value, but they also make the loss of an established partner costly. A terminated relationship can therefore disrupt production even when aggregate trade volumes later recover. Recent research on production networks has accordingly moved beyond trade flows to ask how firm-to-firm links form, survive shocks, and are replaced (Barrot & Sauvagnat, 2016; Carvalho et al., 2021; Bonadio et al., 2021; Choi et al., 2024; Kleifgen et al., 2026).

The adoption of international standards is a natural candidate for shaping this relationship margin, but its role has received much less attention. Standards codify product characteristics, technical interfaces, testing procedures, and quality requirements. When domestic standards are aligned with internationally recognized rules, firms and their foreign partners can work with a more familiar technical language, reducing the need for market-specific adaptation and repeated verification (Swann et al., 1996; Chen & Mattoo, 2008; Fontagné et al., 2015; Schmidt & Steingress, 2022). Standards can also make otherwise difficult-to-observe production and management practices more legible to outsiders, thereby reducing information frictions (Corbett et al., 2005; Terlaak & King, 2006). These features suggest that standards may matter not only for entering foreign markets, but also for keeping existing cross-border relationships intact.

The sign of the effect is not obvious *ex ante*. Common standards may strengthen incumbent relationships because they lower coordination and verification costs, facilitate troubleshooting, and preserve the value of accumulated match-specific knowledge. Yet the same interoperability that makes coordination easier can also expand the set of feasible alternative partners and reduce switching costs. Standardization may therefore either stabilize existing relationships or make replacement less costly. Which force dominates is ultimately an empirical question.

We study this question in Chinese manufacturing, a useful setting because firms are deeply embedded in global production networks while industries differ substantially in both the timing and intensity of domestic alignment with international standards. Our analysis combines three sources of information. FactSet Revere identifies named foreign customers and suppliers and records the observed start and end dates of those relationships. CSMAR provides firm-level financial and governance data. National standards databases report whether Chinese standards correspond to international standards and the degree and timing of that correspondence. Merging these sources yields a firm-year panel covering 2010-2024.

Our dependent variable, *Break*, is a normalized annual termination rate for observed cross-border customer and supplier relationships. We count the foreign relationships that end in a given year and scale that count by the average stock of active relationships in the current and previous year. The normalization separates relationship instability from simple network size. The main explanatory variable, *Std*, is an industry-year stock measure that combines the strength of correspondence between national and international standards with the lag between the international standard and its domestic adoption. In economic terms, *Std* captures the accumulated degree and timeliness of international alignment in the standards environment faced by firms.

The baseline estimates indicate a sizable relationship between standards and link survival. In the preferred specification with firm and year fixed effects and the full set of controls, the coefficient on *Std* is -0.0223. Given the sample standard deviation of *Std*, a one-standard-deviation increase in the adoption measure is associated with a 0.0456 reduction in *Break*, equivalent to roughly 13.4% of its sample mean. The result survives an instrumental-variable design based on industry exposure to ISO technical committees and subcommittees, alternative constructions of both *Std* and *Break*, and sample restrictions that remove centrally administered municipalities and the peak pandemic years. The relationship is also heterogeneous: the association is stronger in less technology-intensive manufacturing, under lower environmental uncertainty, and when firms hold less asset-specific capital.

We also examine a mechanism that is directly interpretable in cross-border exchange: counterparty risk. Foreign customers and suppliers care not only about technical compatibility, but also about whether a partner can continue to

deliver, pay, and remain operational. Internationally aligned standards can make production and quality-control processes more transparent and verifiable, while stronger credit quality reduces concerns about payment and delivery failure. We measure credit quality using the Merton distance-to-default, DD (Merton, 1974; Bharath & Shumway, 2008). The mechanism estimates move in the predicted direction.

The paper makes three contributions. First, it extends the economics of standards from market access and trade margins to relationship persistence. A large literature shows that standards and harmonization affect participation in foreign markets, trade volumes, and product quality (Chen & Mattoo, 2008; Fontagné et al., 2015; Clougherty & Grajek, 2014; Schmidt & Steingress, 2022). Recent work in Review of World Economics likewise emphasizes the trade and quality effects of standards (Kong et al., 2026). We show that international alignment in standards is also related to whether established foreign customer-supplier links survive.

Second, the paper contributes to the growing literature on firm-to-firm production networks. Search frictions, incomplete contracts, input specificity, and accumulated relationship capital make customers and suppliers economically meaningful objects rather than interchangeable trading partners (Nunn, 2007; Antràs & Chor, 2013; Bernard et al., 2019; Choi et al., 2024). Most existing work asks how shocks propagate through these links or how firms replace partners after disruption. We instead study a form of technical infrastructure that may prevent relationship dissolution in the first place.

Third, the paper links standardization to counterparty risk and identifies the conditions under which standards matter most. Certification and standardized procedures can convey credible information when outsiders have difficulty assessing a firm (Terlaak & King, 2006), while financial distress and payment defaults can propagate through customer-supplier relationships (Boissay & Gropp, 2013; Jacobson & von Schedvin, 2015). The credit-quality results connect these two strands. The heterogeneity analysis further shows that the marginal value of standards depends on firms' technological environment, the degree of external uncertainty, and the redeployability of their asset base.

The remainder of the paper proceeds as follows. Section 2 reviews the relevant literature and develops the hypotheses. Section 3 describes the data, variable construction, and empirical strategy. Section 4 presents the baseline estimates, the instrumental-variable results, and robustness checks. Section 5 examines the counterparty-risk mechanism. Section 6 reports the heterogeneity analysis. Section 7 discusses the findings and their limitations, and Section 8 concludes.

2 Literature review and hypotheses

2.1 International standards, harmonization, and international trade

Standards are economic institutions that coordinate expectations about product characteristics, production processes, and technical interfaces. Compatibility standards can create network benefits and reduce interface frictions; quality and process standards can make attributes that are otherwise costly to observe more verifiable. Early evidence showed that shared standards can facilitate trade by lowering technical barriers and improving compatibility (Swann et al., 1996). Later work distinguished among harmonization, mutual recognition, and regulatory measures, showing that the form of standards cooperation matters for both intra- and extra-regional trade (Chen & Mattoo, 2008).

At the firm level, standards shape both the fixed and variable costs of serving foreign markets. Volpe Martincus et al. (2010) show that ISO certification helps firms overcome information barriers and expand exports, while Goedhuys and Sleuwaegen (2013) document productivity and sales gains associated with international certification in developing economies. Clougherty and Grajek (2014) identify common-language and quality-signaling effects of ISO 9000 diffusion on international trade. Fontagné et al. (2015) show that product standards affect firm participation and trade margins, and Schmidt and Steingress (2022) find that harmonized voluntary standards are an economically important channel of trade integration. The common implication is that alignment reduces country-specific adaptation costs, a feature that is particularly relevant in manufacturing supply chains where specifications, tolerances, testing procedures, and interfaces must be coordinated across organizational boundaries.

Standards also have an informational role. When quality or operating capability is difficult to observe, credible external signals can mitigate adverse selection (Akerlof, 1970; Spence, 1973). Certification makes aspects of organizational

practice observable to counterparties that would otherwise be costly to verify. Corbett et al. (2005) document performance changes around ISO 9000 certification, while Terlaak and King (2006) show that certification is especially valuable when buyers face greater information problems. Blind et al. (2018) further find that accreditation and ISO 9000 diffusion reinforce trade by improving the credibility of certification. Beghin et al. (2015) emphasize that standards may either facilitate or impede trade depending on their effects on information, compliance costs, and participation in global value chains. This ambiguity is especially relevant for cross-border transactions, where geographic and institutional distance increase screening and monitoring costs.

2.2 Cross-border buyer-supplier relationships and relationship termination

Production networks consist of repeated firm-to-firm matches, and the structure of those networks determines how microeconomic shocks propagate into aggregate outcomes (Acemoglu et al., 2012). Finding a suitable trading partner is costly, but a successful match allows firms to specialize and combine complementary capabilities. Bernard et al. (2019) show that search and outsourcing costs shape buyer-supplier link formation and firm performance. Using FactSet Revere, Choi et al. (2024) likewise show that social and financial frictions affect the formation of global supply-chain links. Relationship formation is therefore itself an important margin of international trade.

Once a link is established, both sides accumulate match-specific capital. Suppliers adapt products and processes to customer requirements; customers learn about supplier quality and reliability; and both parties develop routines for communication, logistics, quality control, and dispute resolution. The relational view of interorganizational advantage emphasizes the value created by shared routines and complementary resources (Dyer & Singh, 1998), while Ganesan (1994) shows how trust and dependence support a long-term orientation in buyer-seller relationships. In international trade, these relational investments interact with incomplete contracts and input specificity to shape the organization of production (Nunn, 2007; Antràs & Chor, 2013).

Termination destroys at least part of this accumulated capital. A replacement partner must be found, screened, technically qualified, and integrated into the existing production system. When inputs are specific or difficult to substitute, shocks to one firm can therefore propagate to its trading partners. Barrot and Sauvagnat (2016) show that input specificity amplifies the transmission of idiosyncratic shocks. Carvalho et al. (2021) document the propagation of the Great East Japan Earthquake through supply chains, and Bonadio et al. (2021) quantify the role of global supply chains in transmitting pandemic shocks. Recent evidence in Review of World Economics shows that establishments experiencing pandemic-related input difficulties were more likely to switch suppliers, particularly after disruptions to foreign sourcing (Kleifgen et al., 2026).

This literature makes clear why relationship survival is distinct from trade volume. A firm can maintain aggregate imports or exports while repeatedly changing partners, and a relationship can survive temporary volume declines when both sides expect future gains from preserving accumulated match-specific capital. Break is designed to capture this relationship margin directly.

2.3 Standards and the persistence of cross-border relationships

The adoption of international standards can increase the continuation value of an incumbent relationship by lowering coordination and verification costs. Shared technical terminology and testing rules make specifications easier to communicate and reduce the likelihood that incompatible interfaces or ambiguous quality requirements trigger repeated renegotiation. Standards also improve comparability, allowing a foreign partner to assess production processes and product attributes against familiar benchmarks rather than relying entirely on private information supplied by the focal firm.

Standards can also make existing relationships easier to repair. Temporary disruptions need not lead to termination if the parties can diagnose the problem, agree on corrective procedures, and adjust product or delivery requirements within a common technical framework. This matters because established matches embody sunk search, qualification, and adaptation costs. By reducing the cost of adjustment within the match, a common standard can help preserve the value of those investments.

There is, however, an offsetting force. Greater interoperability may make alternative partners easier to integrate. A standardized component can be sourced from a broader set of suppliers, and a standardized product can be offered to a broader set of customers. The net effect on relationship survival is therefore ambiguous. In cross-border manufacturing, we expect the coordination, verification, and repair benefits to dominate because technical standards do not eliminate the private knowledge, trust, and routines accumulated within an established match.

Hypothesis 1. Greater adoption of international standards reduces the termination rate of existing cross-border customer and supplier relationships.

2.4 Credit quality and counterparty risk

Cross-border supply relationships expose both sides to counterparty risk. Customers depend on timely delivery and consistent quality; suppliers may extend trade credit or commit production capacity before receiving payment. Financial distress can therefore damage real production relationships through both payment risk and operating risk. Boissay and Gropp (2013) show that payment defaults transmit liquidity shocks along supply chains, while Jacobson and von Schedvin (2015) document the propagation of corporate failure through trade-credit links.

Internationally aligned standards can reduce perceived counterparty risk by making operating processes more transparent and verifiable. Standardized testing, quality control, certification, and compliance records create information that foreign partners can compare with familiar benchmarks. This logic is consistent with evidence that ISO certification has signaling value when outsiders face information problems (Terlaak & King, 2006) and with cross-country evidence linking international certification to lower financing constraints and stronger firm performance (Ullah et al., 2014). Better credit quality, in turn, makes payment failure, delivery disruption, and involuntary exit less likely.

We measure credit quality using DD, the Merton distance-to-default. The Merton (1974) framework relates default risk to the market value and volatility of firm assets relative to debt obligations, and Bharath and Shumway (2008) evaluate its usefulness for forecasting default. A larger DD indicates that the firm is farther from the default boundary and therefore poses less counterparty risk.

Hypothesis 2. Greater adoption of international standards is associated with stronger credit quality, consistent with a lower-counterparty-risk channel through which relationship termination is reduced.

3 Data and empirical strategy

3.1 Baseline specification

We estimate the relationship between the adoption of international standards and the termination of cross-border customer and supplier links using the following baseline specification:

$$Break_{it} = \alpha_0 + \alpha_1 Std_{jt} + \alpha_2 Controls_{it} + m_i + g_t + \varepsilon_{it} \quad (1)$$

$Break_{it}$ denotes the cross-border supply chain disruption risk of firm i in year t ; Std_{jt} is the international standard adoption efficiency of industry j in year t ; and $Controls_{it}$ is the vector of firm- and province-level controls defined below. The model includes firm fixed effects m_i and year fixed effects g_t , while ε_{it} is the error term. Standard errors are clustered at the firm level. The coefficient on Std is the parameter of interest; a negative estimate indicates a lower termination rate among existing foreign customer and supplier relationships.

3.2 Sample and data

The sample consists of Chinese manufacturing firms listed on the domestic stock exchanges between 2010 and 2024. We exclude financial firms, observations designated ST, *ST, or PT because of financial distress or listing risk, and observations with missing values for the variables required in the analysis. The final baseline sample contains 9,418 firm-year observations.

Cross-border customer and supplier relationships are drawn from FactSet Revere. Revere compiles relationship information from corporate filings, investor presentations, press releases, company websites, and other public primary sources. An important feature of the database is that it records both direct and reverse disclosures, which broadens

coverage beyond relationships reported by the focal listed firm itself. Revere has been used extensively in research on supply-chain exposure and global network formation (Ding et al., 2021; Choi et al., 2024). We retain relationships linking a Chinese listed manufacturer to a foreign customer or supplier and use the recorded start and end years to build an annual relationship panel.

Firm-level financial and governance variables come from CSMAR. Provincial controls are obtained from official statistical yearbooks. Information on national standards and their correspondence with international standards comes from the National Standards Information Public Service Platform and the National Standard Full-Text Disclosure System. ISO technical committee information is obtained from ISO and matched to Chinese manufacturing industries using International Classification for Standards (ICS) codes.

3.3 Variables

3.3.1 Cross-border supply chain disruption risk (Break)

The dependent variable, Break, is the annual termination rate of the focal firm's observed cross-border customer and supplier relationships. We first identify the number of foreign links that end in year t . For each relationship between focal firm i and foreign partner m , Breakrel equals one when the recorded end year is t and zero otherwise. The number of terminated relationships is:

$$Cross_break_{it} = \sum_j Breakrel_{imt} \quad (2)$$

Cross_break is the number of observed foreign customer or supplier relationships of firm i that terminate in year t . A raw count would mechanically be larger for firms with broader international networks, even if their relationships were no less stable. We therefore construct the stock of active cross-border relationships:

$$Cross_stock_{it} = \sum_m 1(Start_year_{im} \leq t \leq End_year_{im}) \quad (3)$$

Cross_stock counts a relationship as active in year t when its start year is no later than t and its end year is no earlier than t . Relationships with no observed end date during the sample period are treated as active through the final observable year. Because new links and terminations can occur within the same year, we use the average of the previous-year and current-year stocks as the exposure base:

$$Avg_Cross_stock_{it} = \frac{Cross_stock_{it-1} + Cross_stock_{it}}{2} \quad (4)$$

The annual relationship termination rate is then defined as:

$$Break_{it} = \frac{Cross_break_{it}}{Avg_Cross_stock_{it}} \quad (5)$$

A higher Break indicates greater termination intensity relative to the firm's cross-border relationship base. Because the denominator is an average stock rather than a strict beginning-of-period exposure count, Break can exceed one when terminations are concentrated in a year with a small average stock. Break should therefore be interpreted as a normalized termination intensity rather than a literal percentage. The measure is designed to capture relationship dissolution rather than network size, consistent with the firm-to-firm supply-chain literature (Choi et al., 2024; Kleifgen et al., 2026).

3.3.2 International standard adoption efficiency (Std)

The core explanatory variable, Std, retains the name used in the original empirical design. Conceptually, it measures the accumulated intensity and timeliness with which national standards in an industry are aligned with corresponding international standards. Source records classify the relationship between national and international standards as IDT (identical), EQV (equivalent), MOD (modified), NEQ (non-equivalent), or no adoption. We assign the ordered scores

4, 3, 2, 1, and 0, respectively. The coding is an empirical ordering of correspondence categories rather than an ISO-prescribed cardinal scale; Section 4.3 therefore reports an alternative coding that gives IDT and EQV the same score.

For standard k associated with industry j , S is the adoption score and Lag is the number of years between publication of the relevant international standard and publication of the corresponding national standard. To avoid division by zero when adoption occurs in the same year, the efficiency of an individual adopted standard is defined as:

$$Eff_{jk} = \frac{S_{jk}}{1 + Lag_{jk}} \quad (6)$$

Eff increases with stronger correspondence to the international standard and with shorter adoption lags. Standards are mapped to two-digit manufacturing industries using the correspondence between the Chinese Classification for Standards and the industry classification. For industry j in year t , $Flow$ aggregates the adoption efficiency of standards matched to that industry-year and divides by the total number of relevant standards. Standards without valid adoption information remain in the denominator but not the numerator, making the measure conservative:

$$Flow_{jt} = \frac{\sum_{k \in (j,t)} \frac{S_{jk}}{1 + Lag_{jk}}}{N_{jt}^{all}} \quad (7)$$

N_{all} is the total number of standards matched to industry j in year t . $Flow$ captures new additions to the internationally aligned standards base in a given year. Because published standards remain available and continue to shape production and coordination after their initial release, these annual flows are cumulated within industry to obtain a stock measure:

$$Std_{jt} = \sum_{\tau \leq t} Flow_{j\tau} \quad (8)$$

The stock measure can equivalently be written as:

$$Std_{jt} = \sum_{\tau \leq t} \left[\frac{\sum_{k \in K_{j\tau}} \frac{S_{jk}}{1 + Lag_{jk}}}{N_{j\tau}^{all}} \right] \quad (9)$$

Std is therefore an industry-year measure of the accumulated international alignment of the standards environment. Higher values reflect stronger correspondence with international standards and shorter adoption lags in the accumulated stock. This construction is consistent with the trade literature showing that harmonization reduces country-specific adaptation costs (Chen & Mattoo, 2008; Fontagné et al., 2015; Schmidt & Steingress, 2022) and with work that treats standards as technical infrastructure for coordination and interoperability (Tassey, 2000; Baron & Spulber, 2018).

3.3.3 Control variables

The firm-level controls are $Listage$, the natural logarithm of years since listing plus one; $Mfee$, management expenses divided by operating revenue; Cap , total assets per employee; Roa , net income divided by total assets; $Loss$, an indicator equal to one when net income is negative; and Lev , total liabilities divided by total assets. Provincial controls include $Open$, goods trade relative to regional GDP after currency conversion, and $Pgdp$, the natural logarithm of GDP per capita. These variables account for differences in firm maturity, operating structure, capital intensity, profitability, financial condition, leverage, regional openness, and local economic development.

3.4 Descriptive statistics

Table 1. Descriptive statistics

Variable	Obs.	Mean	Std. dev.	Min	Max
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Variable	Obs.	Mean	Std. dev.	Min	Max
Break	9,418	0.3400	0.3950	0.0000	1.4444
Std	9,418	6.9418	2.0466	1.8857	11.4307
Listage	9,418	2.4463	0.5199	0.0000	3.3673
Mfee	9,418	0.0737	0.0529	0.0100	0.3248
Cap	9,418	14.5185	0.6575	12.9987	16.2402
Roa	9,418	0.0319	0.0662	-0.2310	0.2050
Loss	9,418	0.1504	0.3574	0.0000	1.0000
Lev	9,418	0.4478	0.1841	0.0653	0.9016
Open	9,418	0.4406	0.2607	0.0071	1.3892
Pgdp	9,418	11.3813	0.4450	9.4861	12.3385

Break has a mean of 0.3400 and a standard deviation of 0.3950, indicating substantial variation in the intensity of relationship termination across firms and years. Std averages 6.9418 with a standard deviation of 2.0466, providing meaningful within-sample variation in the accumulated adoption of international standards. The remaining variables fall within plausible ranges for listed manufacturing firms.

4 Empirical results

4.1 Baseline estimates

Table 2 reports the baseline estimates. Columns (1) and (2) omit firm and year fixed effects, while columns (3) and (4) include both. Controls are added progressively within each pair. The coefficient on Std is negative in every specification and remains statistically significant once the full control vector and fixed effects are included. In the preferred specification in column (4), the coefficient is -0.0223 with a t statistic of -2.4356.

Table 2. Baseline estimates

Variable	(1) Break	(2) Break	(3) Break	(4) Break
Std	-0.0264*** (-15.0552)	-0.0245*** (-12.8651)	-0.0191** (-2.1035)	-0.0223** (-2.4356)
Listage		0.0181** (2.5400)		0.1631*** (3.9961)
Mfee		0.2509*** (2.9711)		0.4421** (2.4562)
Cap		0.0104* (1.9558)		0.0344** (2.0280)
Roa		0.1497* (1.7105)		0.3527*** (2.7301)
Loss		0.0106 (0.6476)		0.0407** (1.9791)

Variable	(1) Break	(2) Break	(3) Break	(4) Break
Lev		0.0641*** (2.6737)		0.0193 (0.3371)
Open		0.0109 (0.5805)		-0.1634** (-2.2177)
Pgdp		-0.0198* (-1.6840)		0.1410* (1.7556)
Firm fixed effects	No	No	Yes	Yes
Year fixed effects	No	No	Yes	Yes
Constant	0.5235*** (39.9667)	0.4808*** (3.5941)	0.4725*** (7.5013)	-1.9947** (-2.1523)
Observations	9,418	9,418	9,418	9,418
R-squared	0.0188	0.0215	0.1863	0.1894

Notes: ***, **, and * denote significance at the 1%, 5%, and 10% levels. Firm-clustered robust t statistics are reported in parentheses.

The estimated magnitude is economically material. Multiplying the preferred coefficient (-0.0223) by the sample standard deviation of Std (2.0466) gives -0.0456. Relative to the mean of Break (0.3400), this is about 13.4%. The association is therefore meaningful not only statistically but also relative to the average annual intensity of relationship termination.

Firm fixed effects absorb time-invariant heterogeneity across firms and year fixed effects absorb common macroeconomic shocks, but neither addresses all remaining endogeneity concerns. For example, industries that become more internationally integrated may both adopt more international standards and develop more stable foreign relationships. We therefore complement the fixed-effects estimates with an instrumental-variable strategy and a set of robustness checks.

4.2 Addressing endogeneity: instrumental-variable estimates

The instrument, Iv, is the cumulative number of ISO technical committees and subcommittees that can be matched to an industry through ICS codes and that had been established by year t. ISO technical committees and subcommittees are the main organizational venues through which international standards are developed and updated. Their historical expansion generates cross-field and time variation in the international standard-setting opportunity set (Baron & Spulber, 2018). Industries connected to a larger stock of relevant committees should therefore have greater access to international standards and stronger opportunities for domestic adoption.

The identifying assumption is that, conditional on firm and year fixed effects and the observed controls, the industry-matched stock of ISO committees affects the termination of an individual firm's foreign customer or supplier relationships primarily through the domestic adoption of international standards. As with any institutional-supply instrument, this exclusion restriction is not directly testable. We therefore treat the IV estimates as complementary identification evidence and keep the causal interpretation appropriately cautious.

Table 3. Instrumental-variable estimates

Variable	(1) Std	(2) Break	(3) Std	(4) Break
	First stage	Second stage	First stage	Second stage
Std		-0.1546**		-0.1657**

Variable	(1) Std First stage	(2) Break Second stage	(3) Std First stage	(4) Break Second stage
		(-2.1503)		(-2.3777)
Iv	0.0259*** (5.0605)		0.0271*** (5.3125)	
Controls	No	No	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Cragg-Donald Wald F	199.493		211.303	
Kleibergen-Paap rk LM	18.701***		20.083***	
Kleibergen-Paap rk Wald F	25.609		28.222	
Observations	6,115	6,115	6,115	6,115
R-squared		-0.0147		-0.0132

Notes: ***, **, and * denote significance at the 1%, 5%, and 10% levels. Firm-clustered robust t statistics are in parentheses. The Kleibergen-Paap statistics assess under-identification and weak identification under heteroskedasticity.

Iv enters the first stage positively and is significant at the 1% level. The Kleibergen-Paap rk Wald F statistics of 25.609 and 28.222 are comfortably above conventional weak-instrument reference values. In the second stage, Std remains negative and significant at the 5% level, both without and with the full set of controls. The IV estimates therefore reinforce the baseline result, subject to the exclusion restriction discussed above.

4.3 Robustness checks

4.3.1 Alternative measures

The first robustness test addresses the ordinal scoring of the standard-correspondence categories. We construct Std_equal by assigning the same score to IDT and EQV while leaving the remaining category weights unchanged. The second replaces the normalized termination rate with Cross_break, the annual number of terminated cross-border relationships. Columns (1) and (2) of Table 4 show that Std_equal remains negatively related to Break, while columns (3) and (4) show that Std remains negatively related to Cross_break.

Table 4. Robustness checks: alternative measures

Variable	(1) Break	(2) Break	(3) Cross_break	(4) Cross_break
Std_equal	-0.0276** (-2.4352)	-0.0311*** (-2.7172)		
Std			-0.2893* (-1.8531)	-0.3169** (-2.0431)
Controls	No	Yes	No	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Constant	0.4972***	-1.9664**	5.4371***	-14.7279

Variable	(1) Break	(2) Break	(3) Cross_break	(4) Cross_break
	(7.7015)	(-2.1199)	(5.0166)	(-0.9696)
Observations	9,418	9,418	9,418	9,418
R-squared	0.1864	0.1895	0.4468	0.4491

Notes: ***, **, and * denote significance at the 1%, 5%, and 10% levels. Firm-clustered robust t statistics are in parentheses.

4.3.2 Sample restrictions

We next exclude the four centrally administered municipalities, whose market institutions, policy environments, and international exposure differ from those of other Chinese cities. We also remove 2020 and 2021 to assess whether the estimates are driven by the exceptional disruption of the COVID-19 pandemic. This is particularly relevant because the pandemic generated unusually large adjustments in international supply chains (Bonadio et al., 2021; Kleifgen et al., 2026).

Table 5. Robustness checks: sample restrictions

Variable	(1) Excl. municipalities	(2) Excl. municipalities	(3) Excl. 2020-2021	(4) Excl. 2020-2021
Std	-0.0163*	-0.0192**	-0.0192*	-0.0225**
	(-1.7140)	(-2.0074)	(-1.9144)	(-2.2031)
Controls	No	Yes	No	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Constant	0.4540***	-0.3881	0.4766***	-1.5483*
	(6.8947)	(-0.2924)	(6.9650)	(-1.6835)
Observations	8,121	8,121	7,424	7,424
R-squared	0.1857	0.1887	0.2274	0.2304

Notes: ***, **, and * denote significance at the 1%, 5%, and 10% levels. Firm-clustered robust t statistics are in parentheses.

Across all four restricted samples, the coefficient on Std remains negative and statistically significant at conventional levels. The baseline finding is therefore not driven by either the distinctive institutional environment of the centrally administered municipalities or the two years most affected by pandemic-related supply-chain disruption.

5 Mechanism: credit quality and counterparty risk

We next ask whether the adoption of international standards is associated with stronger corporate credit quality, a channel that is directly relevant to foreign customers and suppliers. We use DD because its construction follows the structural model of Merton (1974) and the empirical implementation assessed by Bharath and Shumway (2008). The measure is widely interpretable across institutional settings and captures the distance between the market value of a firm's assets and its default boundary. The mechanism specification retains the original empirical equation:

$$Mediator_{it} = b_0 + b_1 Std_{jt} + b_2 Controls_{it} + m_i + g_t + \varepsilon_{it} \quad (10)$$

Mediator_{it} in Eq. (10) is DD_{it}, the distance-to-default of firm i in year t. Std_{jt} is international standard adoption, Controls_{it} is the vector of controls, m_i denotes firm fixed effects, g_t denotes year fixed effects, and ε_{it} is the error term. The regression asks whether greater adoption of international standards is associated with stronger credit quality. We interpret the estimate as evidence consistent with a counterparty-risk channel, not as a formal causal mediation effect.

DD is calculated from the Merton (1974) structural model of corporate debt. Larger values indicate that the market value of the firm's assets is farther from the default boundary and therefore imply lower default risk. We retain the original formula and variable notation:

$$DD_{it} = \frac{Ln(VA_{it} / DT_{it}) + (\phi_{it} - \sigma_{it}^2 / 2)N_{it}}{\sigma_{it} \sqrt{N_{it}}} \quad (11)$$

In Eq. (11), VA_{it} is the market value of firm i 's assets in year t ; DT_{it} is the book value of debt; ϕ_{it} is the expected return on assets; σ_{it} is the total volatility of firm value; and N_{it} is the maturity of the call option. The empirical implementation follows Bharath and Shumway (2008).

Table 6. Mechanism analysis: credit quality

Variable	(1) DD	(2) DD
Std	0.1470*	0.1308**
	(1.9347)	(2.1630)
Controls	No	Yes
Firm fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Constant	5.8304***	9.0354*
	(11.0307)	(1.8827)
Observations	8,268	8,268
R-squared	0.6626	0.6967

Notes: ***, **, and * denote significance at the 1%, 5%, and 10% levels. Firm-clustered robust t statistics are in parentheses.

Std is positive in both DD regressions and statistically significant. With the full set of controls, a one-unit increase in Std is associated with a 0.1308 increase in DD. Because a larger DD indicates lower default risk, the result is consistent with a counterparty-risk channel: firms operating in industries with greater adoption of international standards appear financially more reliable to foreign customers and suppliers. Standards do not eliminate contractual risk, but they can make production and quality-control practices easier to verify and may accompany operating improvements that strengthen financial condition. This interpretation is consistent with the signaling literature on certification (Terlaak & King, 2006) and with evidence linking international certification to lower financing constraints (Ullah et al., 2014).

6 Heterogeneity analysis

6.1 Technology intensity

We first examine whether the relationship between standards and link stability depends on the technological intensity of the industry. To preserve the original empirical grouping, we use the official 2012 CSRC industry codes: firms in C25-C29, C31-C32, and C34-C41 are assigned to the technology-intensive group, and the remaining manufacturing firms form the comparison group. We deliberately use the term technology-intensive rather than high-tech because this grouping is broader than the OECD's strict high-technology category. Its interpretation is nonetheless consistent with the broader OECD practice of classifying manufacturing activities by R&D intensity (OECD, 2015). If standards mainly provide codification, verification, and technical guidance that firms do not already possess internally, their marginal value should be larger in less technology-intensive sectors, where pre-existing standardization and certification capabilities are typically weaker.

Table 7. Heterogeneity by technology intensity

Variable	(1) Technology-intensive	(2) Other manufacturing
Std	-0.0077	-0.0285**
	(-0.3580)	(-2.2627)
Controls	Yes	Yes

Firm fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Constant	-2.9909**	-0.9368
	(-2.5140)	(-0.6747)
Observations	4,815	4,603
R-squared	0.1555	0.2529

Notes: ***, **, and * denote significance at the 1%, 5%, and 10% levels. Firm-clustered robust t statistics are reported in parentheses. The technology-intensity grouping follows the official 2012 CSRC industry codes described in Section 6.1.

The split-sample estimates support this interpretation. Std is negative but statistically insignificant in the technology-intensive group (-0.0077), whereas it is larger in absolute value and significant at the 5% level in the remaining manufacturing sectors (-0.0285). The result suggests that internationally aligned standards provide a larger incremental stabilizing effect where firms begin with less extensive technological and standardization capabilities.

6.2 Environmental uncertainty

Environmental uncertainty captures instability in the firm's operating environment. Dess and Beard (1984) identify environmental dynamism as a central dimension of the organizational task environment, while Ghosh and Olsen (2009) operationalize firm-level uncertainty using sales variability after removing a stable trend component. For each firm-year, we estimate abnormal sales over a rolling five-year window, divide their standard deviation by average sales over the same window, and scale the resulting measure by the corresponding industry-year median. Firms are then split at the sample median. Standards primarily reduce structured technical, informational, and procedural frictions. When demand collapses, logistics fail, geopolitical restrictions change, or other large shocks dominate partner decisions, compatibility alone may be insufficient to preserve a relationship. We therefore expect the stabilizing role of standards to be more visible when environmental uncertainty is relatively low.

Table 8. Heterogeneity by environmental uncertainty

Variable	(1) High uncertainty	(2) Low uncertainty
Std	-0.0045	-0.0480***
	(-0.2779)	(-3.1995)
Controls	Yes	Yes
Firm fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Constant	0.3726***	0.6710***
	(3.3425)	(6.4533)
Observations	4,709	4,709
R-squared	0.2737	0.2742

Notes: ***, **, and * denote significance at the 1%, 5%, and 10% levels. Firm-clustered robust t statistics are reported in parentheses. Firms are split at the sample median of the environmental-uncertainty measure described in Section 6.2.

Std is small and statistically insignificant in the high-uncertainty group (-0.0045), but it is -0.0480 and significant at the 1% level in the low-uncertainty group. The pattern is consistent with standards being most effective when technical and informational frictions are important relative to large external shocks. When market, logistics, or policy shocks dominate the continuation decision, common technical rules alone may be insufficient to keep an incumbent relationship intact.

6.3 Asset specificity

Our final split focuses on asset specificity, a central concept in transaction-cost economics. Specific assets create quasi-rents because their value is lower outside the transaction or relationship for which they were developed (Williamson, 1985; De Vita et al., 2011). Because transaction-level measures of specific investment are unavailable, we retain the

accounting proxy used in the original empirical design: net fixed assets, construction in progress, intangible assets, and long-term deferred expenses, divided by total assets. This measure should be interpreted as the share of long-lived and relatively difficult-to-redeploy capital rather than as a direct measure of relationship-specific investment. That interpretation is consistent with foreign empirical work linking specialized assets to limited redeployability and financing constraints (Balakrishnan & Fox, 1993; Močnik, 2001). Firms are split at the sample median. If highly specific assets already lock firms into existing production configurations, common standards may have less incremental scope to improve relationship portability and repair. We therefore expect a stronger standards effect among firms with lower asset specificity.

Table 9. Heterogeneity by asset specificity

Variable	(1) High asset specificity	(2) Low asset specificity
Std	-0.0010	-0.0332**
	(-0.0765)	(-2.1835)
Controls	Yes	Yes
Firm fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Constant	0.3493***	0.5796***
	(3.9148)	(5.2279)
Observations	4,709	4,709
R-squared	0.2263	0.2389

Notes: ***, **, and * denote significance at the 1%, 5%, and 10% levels. Firm-clustered robust t statistics are reported in parentheses. Firms are split at the sample median of the accounting-based asset-specificity proxy described in Section 6.3.

The results are consistent with this prediction. Std is close to zero and statistically insignificant among firms with high asset specificity (-0.0010), whereas it is -0.0332 and significant at the 5% level among firms with lower asset specificity. The estimates suggest that international standards add more to relationship stability when production assets are easier to redeploy and technical compatibility can translate more readily into partner substitution, adaptation, or repair.

7 Discussion

7.1 Standards and relationship capital

The central finding is that greater adoption of international standards is associated with more persistent cross-border customer and supplier links. This extends the standardization literature beyond the familiar result that harmonization raises trade by lowering adaptation costs (Schmidt & Steingress, 2022). Our evidence points to a different margin: the survival of matches that already exist. That distinction matters because relationship-specific knowledge is itself an economic asset. Losing a foreign partner can require renewed search, screening, qualification, and technical adaptation even when aggregate trade subsequently recovers.

The estimates are consistent with standards functioning as part of the infrastructure of relational governance. Standards do not substitute for contracts or private coordination, but they make core aspects of performance more legible across organizational and national boundaries. Shared rules can reduce disagreement over specifications, create common reference points for troubleshooting, and make quality-control processes easier to verify. This interpretation is consistent with the signaling evidence on ISO certification (Terlaak & King, 2006) and with the broader relational view in which shared routines and complementary resources create value across firm boundaries (Dyer & Singh, 1998).

The mechanism and heterogeneity results sharpen that interpretation. The positive association between Std and distance-to-default is consistent with a counterparty-risk channel rather than with technical compatibility alone. The technology-intensity split suggests that the incremental value of common standards is larger where firms have weaker pre-existing technological and standardization capabilities. The uncertainty results show that standards work best when

structured technical and informational frictions are not overwhelmed by large external shocks. Finally, the asset-specificity results indicate that common standards add less when production is already heavily locked into specialized capital and relationship-specific configurations.

7.2 Relation to recent Review of World Economics research

Recent work in Review of World Economics emphasizes that global value chains adjust through supplier switching, technological repositioning, and changes in non-tariff institutions. Kleifgen et al. (2026) show that pandemic-related input difficulties increased supplier replacement, especially after disruptions to foreign sourcing. Criscuolo et al. (2026) link changes in GVC position to firm-level patenting and technological change. Nenci and Vurchio (2026) examine how non-tariff measures affect agricultural GVC trade, while Kong et al. (2026) study voluntary sustainability standards and quality upgrading. Our paper brings these themes together by pairing a technical institution-the adoption of international standards-with a relationship-level outcome-the termination of foreign customer and supplier links.

More broadly, the paper complements research on how global value chains are organized. Rigo (2021) emphasizes technology transfer through GVC participation, while recent contributions document the roles of supplier networks, non-tariff measures, and voluntary standards in shaping international production (Nenci & Vurchio, 2026; Kleifgen et al., 2026; Kong et al., 2026). We add the survival of existing firm-to-firm relationships as a distinct margin of adjustment.

7.3 Limitations

Several limitations should qualify the interpretation of the results. First, FactSet Revere is built from public disclosures rather than from a census of transactions. It does not observe every supply-chain link, transaction value, or relationship intensity. Direct and reverse disclosures improve coverage, but Break should still be interpreted as termination among observed relationships. This limitation is common in Revere-based research and is one reason we focus on relationship termination rather than transaction values (Ding et al., 2021; Choi et al., 2024).

Second, Std is measured at the industry-year level. It captures the accumulated international alignment of the standards environment faced by firms rather than an auditable firm-level record of exactly which standards each company implemented. We therefore describe the explanatory variable as industry-level adoption of international standards or as the international standard-adoption environment, rather than implying that every sample firm individually adopted each matched standard.

Third, the ISO committee instrument rests on an exclusion restriction. International technological change that stimulates committee formation could also affect supply-chain relationships through channels other than domestic standard adoption. For that reason, the IV results are best viewed as complementary identification evidence rather than definitive proof of causality.

Fourth, the heterogeneity exercises are descriptive splits rather than separate causal designs. The technology-intensity grouping is broader than the OECD's strict high-technology classification; the environmental-uncertainty measure captures firm-specific sales volatility but does not isolate a single exogenous shock; and the asset-specificity proxy is an accounting measure of long-lived and less redeployable capital rather than a transaction-level measure of relationship-specific investment. These limitations motivate cautious interpretation of the subgroup estimates.

8 Conclusion

This paper asks whether the adoption of international standards is related to the stability of cross-border supply-chain relationships. Using 2010-2024 data for Chinese listed manufacturers, FactSet Revere customer-supplier links, and a newly constructed industry-year measure of standard adoption, we find that greater adoption is associated with a lower rate of foreign relationship termination. The estimated magnitude is economically meaningful and remains robust to an instrumental-variable strategy, alternative variable codings, and sample restrictions.

The additional results help explain when and why the relationship emerges. Greater adoption of international standards is positively associated with Merton distance-to-default, consistent with stronger credit quality and lower counterparty risk. The stabilizing association is concentrated in less technology-intensive manufacturing, among firms facing lower

environmental uncertainty, and among firms with lower asset specificity. Taken together, the evidence suggests that standards are most effective when they materially improve codification and verification and when those benefits are not dominated by large external shocks or deep technological lock-in.

The broader implication is that standards can shape international trade at the relationship margin. Their economic role is not limited to market entry or trade values. By lowering coordination and verification frictions and by supporting the reliability of firms operating across borders, internationally aligned standards can help preserve the customer-supplier relationships through which global production is organized. This relationship perspective provides a useful bridge between research on technical standards and research on the resilience and reconfiguration of global value chains.

Statements and Declarations

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Competing interests

The authors declare no competing interests.

Data availability

FactSet Revere and CSMAR are proprietary databases and cannot be redistributed by the authors. The standards data used to construct Std are drawn from public national standards platforms and ISO sources. Replication code for the construction of the authors' derived variables and the empirical analysis can be shared subject to the licensing restrictions imposed by the proprietary data providers.

Use of generative AI in manuscript preparation

OpenAI ChatGPT was used for English-language editing, literature organization, and restructuring for an international readership. It was not used to generate or alter the underlying data, estimate statistical models, or change any reported empirical result. The authors reviewed all substantive claims, references, variable definitions, and the final manuscript and retain full responsibility for the content.

Appendix

Appendix A. Variable definitions

Table A1. Variable definitions

Variable	Definition
Break	Cross-border relationship termination rate defined by Eqs. (2)-(5).
Std	Industry-year cumulative international standard adoption efficiency defined by Eqs. (6)-(9).
Listage	Natural logarithm of years since listing plus one.
Mfee	Management expenses divided by operating revenue.
Cap	Total assets divided by number of employees.
Roa	Net income divided by total assets.
Loss	Indicator equal to one if net income is negative.
Lev	Total liabilities divided by total assets.
Open	Provincial goods trade divided by regional GDP after currency conversion.
Pgdp	Natural logarithm of provincial GDP per capita.

Variable	Definition
DD	Merton distance-to-default, defined by Eq. (11).
Iv	Cumulative number of industry-matched ISO technical committees and subcommittees established by year t.

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