Economics & Business Management
ISSN Print: 3079-5214
ISSN Online: 3079-5222
https://doi.org/10.63313/EBM.9237

Supply Chain Disruption Risk and Return on Assets: The Moderating Roles of Disruption Characteristics in Chinese Semiconductor Industry

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How to cite this paper: Chen, W., & Perez, G. G. (2026). Supply chain disruption risk and return on assets: The moderating roles of disruption characteristics in Chinese semiconductor industry. Economics & Business Management, 7(2), 117–123. ISSN Print: 3079-5214, ISSN Online: 3079-5222.
https://doi.org/10.63313/EBM.9237
Published: 2026-10-22

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Abstract

This paper examines the relationship between supply chain disruption risk (SCDR), three disruption characteristics, and return on assets (ROA) in China's semiconductor industry. Guided by Event System Theory and dynamic capabilities theory, the study treats the disclosure-based frequency, durability, and familiarity indicators as moderators of the SCDR–ROA relationship. The analysis uses annual-report Management Discussion and Analysis (MD&A) disclosures and financial data for 92 Chinese A-share semiconductor firms observed from 2021 to 2025, yielding 460 firm-year observations. The integrated ROA moderation model includes SCDR, all three indicators, their three interactions with SCDR, and controls for total assets, employees, and firm age. The direct SCDR path is negative but not significant. The SCDR by frequency-proxy interaction is negative and significant, while the durability and familiarity interactions are not significant in the baseline specification. The frequency-proxy result remains significant under an alternative semantic-similarity threshold. The evidence links denser disruption-related disclosure to a more negative conditional SCDR–ROA association.

Keywords

Semiconductor Industry; Supply Chain Disruption Risk; Disruption Frequency; Disruption Durability; Disruption Familiarity; Return On Assets; Structural Equation Modeling

1. Introduction

Semiconductor firms operate through a network of specialized activities, including design, wafer fabrication, equipment and materials supply, packaging, testing, logistics, and downstream assembly. The network creates efficiency through specialization, but it also creates dependencies that are difficult to replace quickly.

Disruptions can affect profitability through delayed production, higher procurement and logistics costs, emergency sourcing, idle capacity, and lost sales. Recent supply chain research describes these effects as ripple processes in which a local disturbance spreads through interdependent nodes (Dolgui, Ivanov, and Sokolov 2020; Xiong, Wu, and Yeung 2025).

The financial association of disruption risk may depend on how disruption is described over time. Disruption disclosure frequency (FREQ) measures the density of disruption-related terms in a firm-year MD&A report; Disruption durability (DUR) weights temporal expressions associated with those disclosures; Historical disruption disclosure familiarity (FAM) accumulates prior years' normalized disruption-term densities with time decay. These text-based proxies describe different aspects of reported exposure. This study focuses on ROA and uses a full integrated moderation model. The paper reports the seed lexicons in the appendices.

2. Theory and hypotheses

2.1. Event System Theory

Event System Theory explains organizational consequences through the strength, time, and space of events (Morgeson, Mitchell, and Liu 2015). Conceptually, recurrence and persistence may redirect managerial attention and keep production, procurement, and recovery activities under pressure. In this study, those features are approximated by disclosure-term density and weighted temporal wording, respectively. Familiarity is approximated by prior disclosure intensity rather than observed response experience. The resulting indicators are proxies for theoretically relevant characteristics, not independently verified event histories.

2.2. Dynamic capabilities

Dynamic capabilities theory complements Event System Theory by explaining how firms sense threats, seize response options, and reconfigure resources (Teece 2007). Repeated disruption exposure may exhaust slack through repeated activation; prolonged exposure may keep resources committed; and past exposure may support learning. Because the three characteristics are measured from annual-report language, the empirical tests concern conditional associations between text indicators and ROA, rather than direct observation of these organizational mechanisms.

H1: SCDR is negatively associated with ROA.

H2: Disruption frequency strengthens the negative association between SCDR and ROA.

H3: Disruption durability strengthens the negative association between SCDR and ROA.

H4: Disruption familiarity weakens the negative association between SCDR and ROA because prior experience supports organizational learning.

3. Research design

3.1. Sample and data

The sample contains 92 Chinese A-share listed semiconductor firms observed from 2021 to 2025. The balanced panel provides 460 firm-year observations. Annual-report Management Discussion and Analysis text is obtained from the disclosure database, while ROA, total assets, employee numbers, and firm age are drawn from financial and listing information. Missing firm-years were excluded without imputation.

3.2. Variable construction and formulas

The baseline SCDR1 measure is constructed from a Word2Vec-expanded risk dictionary using a cosine-similarity threshold of θ = 0.60. The dictionary covers supply, demand, process, and environmental disruption terms. An alternative SCDR2 measure uses θ = 0.55 for robustness testing. The text-based construction is represented as:

$$SCDR_{it} = \frac{Count1_{it}}{Total\ Number\ of\ Words\ in\ MD\&A_{it}} \times 100$$

$Count1_{it}$ is the number of occurrences from the final SCDR risk vocabulary in firm i's MD&A report for year t.

The three disruption characteristics are defined as follows:

$$FREQ_{it} = \frac{Count2_{it}}{Total\ Number\ of\ Words\ in\ MD\&A_{it}}$$

$Count2_{it}$ is the number of matches from the frequency dictionary in firm i's year-t MD&A report. It measures disclosure-term density and does not count distinct verified disruption events.

$$\begin{aligned} Total\ Time\ Score_{it} = {} & Total\ Frequency\ of\ Short\ Term\ Words \times 1 \\ & + Total\ Frequency\ of\ Medium\ Term\ Words \times 2 \\ & + Total\ Frequency\ of\ Long\ Term\ Words \times 3 \end{aligned}$$

$$DUR_{it} = \frac{Total\ Time\ Score_{it}}{Count2_{it}}$$

$Count2_{it}$ is the denominator for DUR. The weighted numerator is based on short-, medium-, and long-term expressions with scores of 1, 2, and 3. DUR therefore measures the density of persistence-related language per disruption keyword; it is not observed elapsed duration.

$$FAM_{it} = \sum_{s=1}^{t} \delta^{(t-s)} \times \frac{Count2_{is}}{Total\ number of\ words\ in\ MD\&A_{is}}$$

δ = 0.7 is the time-decay coefficient; more recent prior disclosures receive greater weight.

t − s is the number of years between the current year t and an earlier years.

3.3. Full Integrated ROA Moderation Model

The full integrated ROA moderation model includes SCDR, the three disruption-characteristic proxies, their three interaction terms, and the controls. The model is specified as:

$$ROA_{it} = \beta_0 + \beta_1 SCDR_{it} + \beta_2 FREQ_{it} + \beta_3 DUR_{it} + \beta_4 FAM_{it} + \beta_5(SCDR_{it} \times FREQ_{it}) + \beta_6(SCDR_{it} \times DUR_{it}) + \beta_7(SCDR_{it} \times FAM_{it}) + \gamma_1 lnNE_{it} + \gamma_2 lnTA_{it} + \gamma_3 Age_{it} + \varepsilon_{it}$$

FREQ, DUR, and FAM are moderators. Their interaction coefficients test whether the conditional SCDR–ROA slope changes as each text-derived characteristic varies.

4. Full Integrated ROA Moderation Model Fit and Estimation Adequacy

The full integrated ROA moderation model met the stated fit criteria. The reported fit statistics were χ^2 = 73.95 with 58 degrees of freedom, χ^2/df = 1.27, p = .077, CFI = .995, TLI = .992, RMSEA = .024, GFI = .976, and AGFI = .963. The ROA equation contains ten predictor coefficients: SCDR, three disruption characteristics, three interaction terms, and three controls, plus an intercept and residual term. Predictor diagnostics ranged from VIF 1.485 to 6.113; no VIF exceeded 10.

5. Results

Table 1 reports the complete ROA path-coefficient table for the full integrated moderation model. It includes every predictor in the ROA equation, including the three disruption characteristics, all three interaction terms, and the three controls.

Table 1. Complete path coefficients for ROA in the full integrated moderation model

Predictor	B	β	SE	z	p	Sig.
SCDR	−0.0146	−0.1325	0.0105	−1.398	.162	
FREQ	4.9723	0.5129	1.0292	4.831	<.001	***
DUR	0.0736	0.1751	0.0290	2.542	.011	*
FAM	−1.5088	−0.4687	0.2065	−7.307	<.001	***
SCDR× FREQ	−1.8586	−0.1770	0.7590	−2.449	.014	*
SCDR× DUR	0.0199	0.0351	0.0378	0.526	.599	
SCDR× FAM	0.2132	0.0514	0.2696	0.791	.429	
Firm Size (lnTA)	0.0129	0.2060	0.0051	2.521	.012	*
No. of Employees (lnNE)	−0.0084	−0.1355	0.0051	−1.655	.098	
Firm Age	−0.0003	−0.0349	0.0005	−0.667	.505	

Note. B is the unstandardized coefficient and β is the standardized coefficient. SCDR, FREQ, DUR, and FAM were mean-centered before interactions were calculated. *** p < .001, ** p < .01, * p < .05.

The direct SCDR coefficient is negative but not significant (B = −0.0146, p = .162). The frequency main effect is positive and significant, and the durability main effect is positive and significant. Familiarity has a negative and significant main effect. Because the model includes interactions, these main effects represent conditional effects at the sample mean of the interacting variables after centering; they should not be read as unconditional causal effects.

The focal interaction is SCDR × FREQ → ROA. Its coefficient is negative and

significant (B = −1.8586, β = −0.1770, p = .014), indicating that the estimated SCDR–ROA slope becomes more negative as the FREQ disclosure-density proxy rises. The SCDR × DUR coefficient is positive and non-significant (B = 0.0199, p = .599). The SCDR × FAM coefficient is positive and non-significant (B = 0.2132, p = .429). Thus, in the baseline model, only the frequency proxy shows evidence of moderating the SCDR–ROA association.

6. Robustness analysis

The robustness analysis replaces SCDR1 with SCDR2, constructed using a Word2Vec cosine-similarity threshold of θ = 0.55. The two measures show substantial agreement: Pearson r = .786 and Spearman ρ = .751, both p < .001. The same full integrated ROA moderation equation is then re-estimated with SCDR2 and its three interaction terms.

Table 2. Comparison of Baseline SCDR1 and Alternative SCDR2 Structural Results

ROA path	Baseline SCDR1	Alternative SCDR2	Assessment
SCDR → ROA	B = −0.0146, p = .162	B = 0.0122, p = .103	Both non-significant
SCDR × FREQ → ROA	B = −1.8586, p = .014	B = −1.1684, p = .012	Negative and significant in both
SCDR × DUR → ROA	B = 0.0199, p = .599	B = −0.0616, p = .009	Sensitive to SCDR construction
SCDR × FAM → ROA	B = 0.2132, p = .429	B = 0.0658, p = .700	Non-significant in both

The frequency-proxy interaction is the most stable result. It is negative and significant under both semantic thresholds. The durability interaction changes direction and significance, so it should not be treated as robust evidence. The familiarity interaction remains non-significant. These checks support a measurement-sensitive interpretation of the text-derived characteristics.

7. Discussion

The full ROA model shows why the overall SCDR score should be interpreted alongside the characteristics derived from disclosure text. The direct SCDR path is not significant after the three proxies and their interactions are included. Higher FREQ scores, however, are associated with a more negative conditional SCDR–ROA slope. Repeated operating interventions are one possible explanation, but the annual-report measure does not identify separate incidents or measure their costs. This mechanism remains to be tested with operational records.

Durability and familiarity remain theoretically meaningful. Persistence could sustain capacity and cost pressure, while prior exposure could influence learning and response. The current DUR score summarizes temporal wording, and FAM summarizes earlier normalized term densities. Neither directly measures elapsed disruption time or organizational learning. Their interaction terms are not stable in the present ROA analysis: DUR changes under the alternative SCDR construction, and FAM is non-significant in both specifications.

For managers, the measures could form a four-indicator disclosure dashboard. SCDR summarizes overall reported risk; FREQ flags denser disruption-related wording; DUR flags more persistent temporal language; and FAM summarizes earlier disclosure intensity. The FREQ proxy merits closer review when profitability is monitored, but any operational response should be checked against procurement, production, and supplier incident records before treating the text signal as a confirmed disruption.

8. Conclusion

This paper specifies an integrated ROA moderation model using text-derived indicators of disruption risk and its characteristics. The direct SCDR–ROA association is not significant. The frequency disclosure-density proxy shows a reproducible negative interaction with SCDR, whereas the durability and familiarity interactions are not stable. The result identifies an association in reported risk language and profitability; verified event counts, elapsed disruption time, and observed response experience remain priorities for future validation.

Appendix A SCDR Seed Lexicon

The SCDR seed lexicon follows four risk-source groups used in the text-measurement design. The table reports the English seed terms used to identify risk-related wording in the disclosure-text dictionary.

Table 3. SCDR Seed Lexicon

Risk group	English seed terms
Supply disruption risk	Supplier; Upstream; Raw materials; Core components; Key materials; Procurement; Supply; Supply interruption; Delayed delivery; Supply shortage; Wafer; Silicon wafer; Chip; Lithography machine; EDA tools; Packaging and testing; Semiconductor equipment
Demand disruption risk	Demand fluctuations; Order reduction; Order cancellation; Demand decline; Customer churn; Inventory backlog; Market volatility; Industry cycle; Downstream demand
Process disruption risk	Production interruption; Work stoppage and production halt; Equipment failure; Process defect; Capacity bottleneck; Yield decline; Yield rate; Manufacturing process; Wafer fab
Environmental and geopolitical risk	Geopolitics; Trade friction; Export restrictions; Policy control; Sanctions; War; Pandemic; Natural disasters; Chip ban; Entity list; Technology restrictions

Operational note. The risk groups are combined to construct the SCDR text signal. Word2Vec expansion is then applied with the baseline cosine-similarity threshold $\theta = 0.60$ and the alternative threshold $\theta = 0.55$.

Appendix B Disruption Characteristic Seed Lexicon

This appendix lists the seed terms used for the FREQ disclosure-density proxy and the temporal expressions used for the DUR proxy. FREQ is based on normalized keyword occurrences, not a count of distinct events. DUR weights short-, medium-, and long-term expressions, not elapsed days or months.

Table 4. Disruption Characteristic Seed Lexicon

Characteristic	English seed terms
Frequency terms	Supplier; Upstream; Raw materials; Core components; Key materials; Procurement; Supply; Supply disruption; Supply shortage; Delivery delay; Export restriction; Technology restriction; Demand fluctuation; Demand decline; Order reduction; Order cancellation; Customer loss; Inventory backlog; Industry cycle; Downstream demand; Production disruption; Production shutdown; Equipment failure; Process defect; Capacity bottleneck; Yield decline; Process technology; Geopolitics; Trade friction; Policy regulation; Sanctions; War; Pandemic; Natural disasters; Chip ban; Entity list
Durability category	English temporal seed terms
Short-term score 1	Short-term; Short-term shock; Temporary; Phased; Short-term fluctuation
Medium-term score 2	Several months; Quarterly; Continuous; Ongoing; Gradual recovery
Long-term score 3	Long-term; Lasting; Long-term impact; Persistent impact; Continuing to the present; Not yet recovered; Full-year

Operational note. FREQ equals Count2 divided by total MD&A words. DUR uses weighted temporal-expression scores divided by Count2. FAM is calculated from earlier years normalized Count2/MD&A-word values with exponential decay ($\delta = 0.7$); it is not an accumulation of the scaled SCDR1 index.

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