

Systematic review

## Impact of Geopolitical Risks on Global Supply Chain Strategies: Evidence from the Semiconductor Industry

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### Abstract

This study argues that geopolitical risk, not cost efficiency, now decisively structures semiconductor supply chains. Using a systematic literature review (SLR) of 2020-2025 sources and reflexive thematic analysis, it synthesizes four findings. First, sanctions, export controls and critical-mineral dependencies have converted long-known chokepoints (advanced lithography, leading-edge foundries, and specialist materials) into systemic vulnerabilities. Second, firms are not simply “decoupling” but adopting a triad of adaptations: asset re-location (reshoring and nearshoring and dual footprints), supply-base diversification with pre-approved alternates across tiers, and digital risk instrumentation (predictive analytics, control-tower visibility, scenario stress-testing). These moves raise resilience but impose material trade-offs in capital intensity, operating cost and talent constraints. Third, sovereignty-driven policies (e.g., subsidy regimes and export controls) are only partially effective: they crowd in investment yet risk regulatory fragmentation, retaliation, and distorted competition that can reallocate rather than reduce systemic exposure. Finally, the review rejects single-theory explanations. Global Value Chain mapping clarifies interdependence; Resource-Dependency analysis explains power asymmetries; resilience frameworks capture operational levers, none suffice alone. The conclusion is prescriptive and arguing that shift from reactive crisis management to anticipatory, data-driven resilience that hardens critical nodes, expands dual sourcing beyond tier-1 visibility, and aligns industrial policy with interoperable standards to avoid a subsidy-arms race that undermines the very robustness it seeks to build.

**Keywords:** semiconductors; geopolitics; supply-chains; resilience; reshoring; diversification; industrial-policy

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### 1. Introduction

Semiconductors underpin economic growth across artificial intelligence, 5G and electrified mobility, yet the organizing logic of this industry has moved from cost efficiency to strategic security. Global semiconductor sales grew to 627.6 billion dollars in 2024 and are projected to expand further in 2025, which elevates the macroeconomic cost of any disruption and intensifies political competition over supply access and control (Peterson, 2025). The geography of production remains acutely concentrated. Taiwan, South Korea and China dominate leading manufacturing stages. TSMC has announced 165 billion dollars of new US capacity to diversify exposure to regional shocks, while Korean exports oscillated in early 2025 with memory demand and tariff risk. China has lifted investment in front end equipment to reduce import dependence under tightening controls (McMorrow et al., 2025; Yonhap News Agency, 2025; AINVEST, 2025; Lee, 2025). The United States is counter-concentrating capacity through vast private and subsidised programmes, from Nvidia’s commitment to domestic manufacturing to GlobalFoundries’ CHIPS-backed expansion in New York (Bradshaw and Acton, 2025; Rulison, 2025). These shifts are not parallel coincidences. They

reveal an industry where the risk frontier is co-produced by states and firms, and where chokepoints are instruments of power rather than mere technical constraints.

The inherited supply architecture is brittle by design. A single region controls more than half of many value-chain stages, with at least 65 percent global share at over fifty nodes, magnifying correlated failure when shocks hit a hub (Ravi, 2021; Slotta, 2024). Just-in-time disciplines that once freed working capital now transmit disturbances faster than firms can replan, as COVID-19 shutdowns and port congestion demonstrated (ITSupplyChain, 2023; Vernall, 2024). Semiconductor production involves thousands of steps and multi-tier webs where minor perturbations propagate into cascading yield losses and missed ramps, a dynamic amplified by long lead times and short product lifecycles (Gomez et al., 2020; Seitz et al., 2016; Octopart, 2023). Equity markets price this brittleness through greater volatility for firms embedded in fragile networks (Davletshin et al., 2018). Geopolitical instruments expand the hazard set. China's licensing of gallium, germanium and antimony, and allied United States export controls on advanced tools and compute silicon, rewire access to inputs and equipment overnight, forcing emergency redesigns of sourcing portfolios and product roadmaps (China News, 2024). Nvidia's pivot to significant US manufacturing illustrates how leading firms now internalise political risk in capital allocation, not just in compliance (Makortoff, 2025).

The strategic driver is the escalating United States China rivalry. The United States has blacklisted dozens of Chinese entities and extended extraterritorial licensing to constrain access to high-end compute and manufacturing capability, while China has doubled down on indigenous innovation after sanctions on Huawei and SMIC (Sevastopulo, 2025; Weatherbed, 2025; Li, 2024; Tse et al., 2024; Yan, 2023). The policy turn is systemic. The US CHIPS and Science Act mobilises 52.7 billion dollars, while the EU Chips Act seeks to double market share by 2030. Both articulate techno-nationalist aims of sovereignty and trusted supply, often at odds with earlier global value chain assumptions (Citigroup, 2024; European Commission, 2023; Hyatt et al., 2024; Sterling, 2025). Key East Asian allies align export-control stances with Washington, de-prioritising pure cost efficiency in favour of resilience and alliance politics (Aoyama et al., 2024). Taiwan's centrality is both an asset and a systemic liability, given cross-Strait risk and TSMC's dominance in advanced logic (Efficio, 2024; Liu et al., 2024; Klingler-Vidra & Kuo, 2021). The net result is a bifurcating trade-technology regime in which standards, subsidies and sanctions co-evolve.

The United Kingdom exemplifies the double bind of capability and exposure. The UK is strong in design through Arm and a dynamic SME base but lacks leading-edge fabrication and relies on offshore foundries and upstream toolmakers (Zhang, 2020). The national strategy pledges one billion pounds over a decade and Innovate UK grants aim to scale domestic strengths, while industry output is forecast to grow from ten to 25.09 billion pounds by 2034. Yet Brexit frictions with EU partners like ASML complicate collaboration and access, and strategic ambiguity toward China sustains risk surfaces beyond London's direct control (Expert Market Research, 2024; Robinson, 2024; Chatham House, 2023; GOV.UK, 2025; UKRI, 2024; Klingler-Vidra & Kuo, 2021; Chiang, 2023; Financial Times, 2024; Owen, 2024). The UK case reinforces a broader thesis. Governance choices, not just technology, set the feasible set for resilience.

The pandemic provided the sharpest validation of fragility claims. Automotive output fell 26 percent in the first nine months of 2021, destroying 210 billion dollars in revenue as chip shortages cascaded through global platforms. Telecom and healthcare suffered component scarcity that delayed product rollouts and critical devices (JP Morgan, 2023; Bender, 2023; Francis, 2020; STL Partner, 2023; Kleinhans & Hess, 2021; Mohammed & Khan, 2022). Remote-work demand spikes collided with fab shutdowns, container shortages and labour immobility, overwhelming capacity. Firms with diversified suppliers, localised options and AI-enabled forecasting adapted faster, demonstrating that resilience is performance-relevant rather than a public relations claim (Ekatpure, 2024; Zhu, 2023; Ramani et al., 2022; Ishak et al., 2022).

Conventional theory illuminates parts of this landscape yet leaves a gap. Global Value Chain theory maps dispersion and upgrading but under-models coercive policy shocks and node-specific risk when a single fabricator controls most advanced logic below 5 nm (Dorakh, 2024; Huang, 2024). Resource Dependency Theory captures power asymmetry around critical inputs and IP such as EUV lithography and Arm architecture, but it privileges firm agency over legal-regulatory constraint and the path dependence of equipment monopolies (Odell et al., 2021; Ning et al., 2023; Jiang et al., 2023). Resilience theory adds operational levers like buffers, dual sourcing and agile planning, but it often reduces geopolitical turbulence to probabilistic shocks rather than recognising strategic feedback from sanctions and countersanctions (Mishra et al., 2024). A hybrid lens is necessary. Semiconductor supply is shaped by structural chokepoints, bargaining asymmetries and policy instruments that jointly determine exposure and adaptation.

Industry structure magnifies the stakes. The fabless-foundry model improves efficiency yet deepens interdependence across design, fabrication and assembly with more than a thousand steps and dozens of cross-border movements per device. Spatial clustering raises productivity but concentrates risk, particularly where TSMC's advanced fabs sit in seismic and geopolitical exposure zones (Filippo et al., 2022; Hillrichs & Wölfl, 2025; Yeung, 2022). System behaviour mirrors complex networks. Load redistribution, delay propagation and multi-layer coupling can turn small disturbances into discontinuous failures without redundancy and tier-2 and tier-3 visibility (Lu and Li, 2024; Yang et al., 2021; Gomez et al., 2020). Critical nodes like ASML's EUV monopoly and Arm's IP dominance create single-point sensitivities that cannot be hedged through simple inventory alone (Ning et al., 2023; Odell et al., 2021).

Firm responses have converged on a triad of adaptations. Asset re-location through reshoring and nearshoring seeks to shorten supply lines and align with friendly jurisdictions. Predictive analytics and control-tower visibility promise earlier detection and faster re-planning. Supply-base diversification extends beyond dual sourcing at tier-1 to pre-approved alternates deeper in the stack. Yet each lever incurs trade-offs. US fabs are 20 to 40 percent costlier than East Asian equivalents and talent shortages threaten ramp timelines. Digital tools require data governance that many firms lack. Raw-material chokepoints in gallium, germanium and cobalt limit how far geographic diversification can offset upstream concentration (Teer & Bertolini, 2023; Deloitte, 2024; PwC, 2025; Lee, 2025; Allianz Trade, 2025; Shin, 2024; GlobalFoundries, 2024; Alicke et al., 2024).

Public policy has moved from rhetorical concern to large chequebooks and restrictive trade instruments. The CHIPS Acts and export controls change incentives but carry unintended consequences. Capacity expands more slowly than capital is committed because skills, permitting and supplier ecosystems bind. Fragmented subsidy regimes risk duplication, jurisdictional friction and inequity that favours incumbents. Export controls may accelerate import substitution by targeted states. Without coordination, the system can reallocate rather than reduce exposure (European Commission, 2023; DSIT, 2023; WTO State-Aid Scoreboard, 2024; Matamis, 2025; Mariotti, 2024; Broeders et al., 2023; Xueji, 2025; Min & Kim, 2025; US BIS, 2024).

The prevailing approach to semiconductor resilience is fragmented and reactive. Firms are layering buffers, second sources and regional footprints on top of architectures that remain anchored to a small number of capital-intensive and policy-sensitive nodes. States are spending aggressively but with limited coordination and uneven attention to skills, standards and interoperability. The result is a costlier system that still hinges on the same bottlenecks, now politicised through sanctions, licensing and subsidies. Scholarship mirrors this fragmentation. Many studies examine policy or firm practice in isolation, with limited synthesis across operations management and international political economy. What is missing is a sector-specific, empirically grounded account of how geopolitical instruments and industrial structures interact to produce exposure and to shape the efficacy of adaptation.

This study conducts a systematic literature review to explain how geopolitical risks between 2020 and 2024 reshaped semiconductor supply chain strategies, resilience and policy responses. Conceptually, it fuses Global Value Chains, Resource Dependency and Resilience perspectives into a single framework that treats geopolitics as an endogenous design choice rather than an external shock. Empirically, it consolidates peer-reviewed and industry evidence to identify which adaptations actually sustained continuity and recovery, at what cost, and under which policy regimes. It answers five questions: which geopolitical risks most affected semiconductor supply chains in 2020-2024; how firms restructured and built resilience in response; what concrete mitigation levers proved effective; how trade policy, regulation and national security controls shaped managerial decisions; and what trends and implications now define the next phase of semiconductor supply chain management. The study prescribes tier-deep diversification, qualified alternates, predictive visibility and allied policy coordination, warning that subsidies and nearshoring alone raise costs without securing supply.

## **2. Methodology**

A Systematic Literature Review (SLR) was conducted under PRISMA 2020 guidance (Page et al., 2021) and synthesised using Reflexive Thematic Analysis (RTA) (Braun and Clarke, 2006). The approach is explicitly interpretivist, justified by the socially constructed and context-contingent nature of “geopolitical risk,” and is implemented with an auditable protocol covering search, selection, appraisal, extraction, analysis, and reporting. Citations follow the Harvard system consistent with Saunders, Lewis and Thornhill (2019). Interpretivism anchors the design because firm responses to sanctions, export controls and subsidy regimes are mediated by managerial meaning-making, institutional logics and shock timing. Ontologically, the study treats risk as negotiated among states, firms and supply-chain partners; epistemologically, it privileges situated understanding over universal generalisation. The implication is an inductive design that looks for patterned explanations rather than average treatment effects. A doctrinally disciplined SLR is therefore suitable: it aggregates heterogeneous, cross-disciplinary evidence while preserving a transparent decision trail that others can interrogate (Tranfield et al., 2003). RTA then provides the analytic engine to convert a vetted corpus into theoretically coherent themes without forcing premature quantification (Braun and Clarke, 2006).

Evidence on semiconductor geopolitics is fragmented across management, international political economy and engineering outlets. Narrative reviews are vulnerable to cherry-picking and lack reproducibility. A formal SLR constrains researcher discretion through ex-ante decisions about databases, search strings, eligibility thresholds and appraisal criteria. PRISMA 2020’s flow-diagram discipline obliges full documentation of identification, screening, eligibility and inclusion, increasing transparency and confirming that exclusions were methodological, not ideological (Page et al., 2021). Because managerial practice is the target audience, the SLR’s auditability strengthens utility: practitioners can trace the evidential basis for each claim. The temporal window begins in early 2020 to capture pandemic-triggered ruptures and closes in April 2025 to include the second tranche of U.S. export controls and the first EU Chips Act subsidy calls. The unit of analysis is the firm-level strategic response, not the macro-design of policy. Five questions guide the review: which discrete geopolitical shocks most affected semiconductor supply chains in

2020–2024; how firms reconfigured networks and processes; which governance, technological or locational levers proved most salient; how trade restrictions, export controls and subsidies shaped decisions; and which 2024-2025 trajectories foreshadow future supply-chain geometry. The questions are deliberately open to inductive patterning but remain tightly focused on managerial practice. No single repository covered the interdisciplinary span. To minimise omission risk while managing noise, five complementary sources were used: Scopus and Web of Science for breadth and citation analytics; ScienceDirect for operations and engineering journals; IEEE Xplore for process-technology proceedings; and Google Scholar to net grey literature, policy briefs and vetted consultancy reports. Redundancy was controlled by DOI cross-checking.

Searches were run on 20 April 2025 in title, abstract and keyword fields on Google scholars. Filters limited retrieval to English-language, peer-reviewed articles, conference papers and institutionally vetted reports. The architecture combined controlled vocabulary, wildcards and Boolean operators. A representative query was:“(semiconductor\* OR ‘integrated circuit’ OR IC) AND (supply chain OR logistics OR fab) AND (geopolitical OR sanction\* OR ‘export control’ OR decoupling OR ‘critical mineral’) AND (strategy OR resilien\* OR response OR reshoring OR ‘friend-shoring’ OR ‘China plus one’).” The initial harvest yielded 312 unique records after de-duplication.

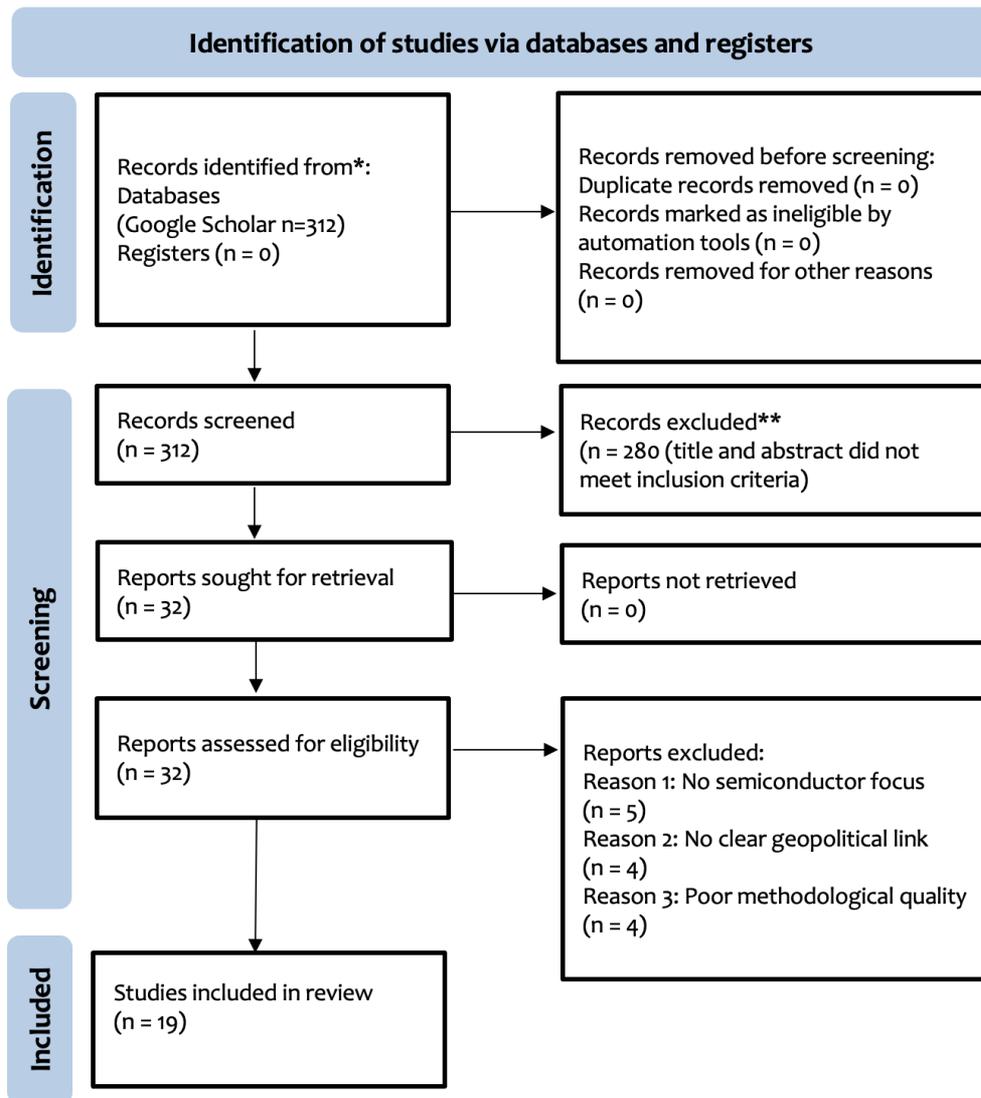


Figure 1. PRISMA flowchart (Page et al., 2021).

Selection proceeded in two sequential tiers to keep only work that is both relevant and methodologically sound. Tier 1 comprised title-and-abstract screening by two independent reviewers following a piloted rubric. Agreement after a 30-record calibration round reached Cohen’s  $\kappa = 0.84$ , classed by Landis and Koch (1977) as “almost perfect,” evidencing that the relevance rules were clear and consistently applied. Tier 2 was full-text appraisal against pre-specified inclusion criteria: (i) semiconductor sector focus; (ii) explicit causal linkage between a geopolitical factor (e.g., export controls, sanctions, subsidy races) and a supply-chain strategy; and (iii) primary data or a transparent analytical framework for conceptual pieces. Exclusions targeted opinion-only articles, methodologically opaque studies, and tangential sectors (e.g., photovoltaics), unless they yielded transferable insight into semiconductor inputs (e.g., polysilicon constraints).

Thirty-two studies passed the eligibility and quality was graded using a dual-track checklist matched to method: CASP for qualitative designs and Kitchenham and Charters (2007) for empirical software-engineering-type studies. Each article was scored on relevance, methodological transparency, data integrity and analytical depth, equally weighted (0.25 each). A conservative 50% composite threshold ensured that only substantively and methodologically credible work informed the synthesis. This yielded a final corpus of 19 high-quality sources that underpin the thematic analysis in Chapter 4. The staged reduction from 312 to 19 is documented in a PRISMA-style flow (Figure 5), satisfying PRISMA 2020's traceability requirements (Page et al., 2021). To keep interpretation grounded in the evidence actually reported, a custom Excel extraction matrix captured fourteen fields per study: Authors; Year; Study site; Title; Journal; Methodology; Conclusion; and Relevance to Research Aim, alongside additional metadata necessary for cross-study comparison. To check accuracy, double data entry was applied to a 15% random sample; error rates below 5% were achieved, meeting qualitative dependability benchmarks (Guba, 1989). This structured extraction ensures that later thematic claims can be traced to precise passages and designs within the underlying articles.

RTA fits the interpretivist stance because it privileges meaning, context and researcher reflexivity over mechanical code counting (Braun and Clarke, 2006). The analysis followed six iterative phases. Phase 1 (familiarisation) required two passes through each article, with reflective memos capturing nascent regularities in disruptions, adaptations and regulatory interfaces. Phase 2 (coding) used a hybrid approach: deductive codes drawn from resilience constructs, redundancy, visibility, flexibility and collaboration (Ponomarov and Holcomb, 2009), were combined with inductive codes emerging from the data, allowing novel phenomena such as "fab-shell opportunism" to surface rather than be forced into pre-existing bins. Phase 3 (theme development) clustered codes into conceptually coherent candidates, stress-testing internal homogeneity and external heterogeneity via constant comparison. Phase 4 (review) tightened boundaries, re-coded misfits and documented decisions in analytic memos to preserve the audit trail. Phase 5 (definition and naming) articulated the core organising concepts for each theme, prioritising analytic salience over frequency (Jackson and Bazeley, 2019). Phase 6 (integration) prepared themes for narrative synthesis in Chapter 4, aligning evidential exemplars with the research questions. This sequence is justified on two grounds. Substantively, it captures multi-scalar dynamics spanning plant-level logistics, corporate network design and policy firm feedbacks. Methodologically, it resists the spurious precision of counting codes where meaning and context are the explanandum.

The design embeds rigour at every gate. Transparency is delivered by fully documenting search dates (20 April 2025), fields (title/abstract/keywords), filters (English; peer-reviewed articles, conference papers, institutionally vetted reports) and the exact search architecture. Dependability is buttressed by the two-tier screening with  $\kappa = 0.84$ , double data entry checks and a fixed, pre-announced quality threshold. Confirmability is supported by preserving memos and extraction spreadsheets, enabling external scrutiny of how interpretations were derived from the data. Credibility is strengthened by the method-matched appraisal tools (CASP; Kitchenham Charters), which avoid penalising qualitative richness or privileging quantitative designs a priori. Finally, potential researcher bias is handled by explicit disclosure: one author's prior semiconductor industry experience and another's funding from a trade-policy organisation are acknowledged, so readers can evaluate whether positionality influenced theme construction (Whittemore & Knafelz, 2005). The practical effect is to make the chain of evidence visible and challengeable, which is essential for applied fields where policy and investment decisions may rely on the findings.

Because all materials were secondary and publicly accessible, formal ethics-committee approval was not required under institutional policy. Nevertheless, the study adhered to ethical scholarship by accurate citation, respect for copyright (especially for consultancy exhibits) and avoidance of argument misrepresentation. Pre-prints were included only after cross-checking against subsequent peer-reviewed versions to reduce the risk of relying on superseded datasets. Three constraints are candidly acknowledged because they delimit the claims the study can make. First, restricting to English may omit rigorous Chinese or Korean studies, potentially muting insights into domestic mitigation strategies such as "dual circulation." Second, publication lag means that strategic shifts disclosed in late-2024 earnings calls or investor days may not yet be peer-reviewed, creating a temporal blind spot; where such items informed inclusion, they entered only if captured by institutionally vetted reports within the database filters. Third, qualitative synthesis forgoes statistical generalisation; that is a deliberate trade-off aligned with interpretivism, privileging contextual understanding over cross-sectional averages (Pratt, 2009). These limitations frame interpretation; they do not undermine the internal coherence or transparency of the findings.

Methodological choices are tightly coupled to the study aims. The firm-level focus and interpretivist stance justify the SLR's breadth combined with strict eligibility that demanded an explicit causal link from geopolitical factor to supply-chain response. The two-gate screening and dual-track appraisal convert a wide initial net (312 records) into a credible corpus of 19 without smuggling in convenience sources. The extraction matrix ensures that claims in section 4 can be traced to specific studies and designs. The hybrid coding in RTA honours existing resilience theory while leaving room for novel mechanisms peculiar to semiconductors (e.g., lithography chokepoints, gas inputs), which an a priori scheme might miss. The audit trail, search logs,  $\kappa$  statistic, PRISMA flow, memos, allows other scholars and practitioners to reproduce or challenge each step. In sum, this methodology is intentionally lean and defensible. It combines an interpretivist SLR under PRISMA 2020 with reflexive thematic analysis to produce context-sensitive, managerially actionable insights. Every stage, from database choice and time-stamped search to dual-review

screening, method-matched quality appraisal, structured extraction, hybrid coding and memoed theme construction, has been justified in relation to the study's purpose: to explain how semiconductor firms re-designed supply chains under geopolitical stress between 2020 and April 2025. The approach trades statistical generalisation for depth, transparency and theoretical fit, thereby delivering a reliable platform for synthesis and the practice implications that follow.

### **3. Results**

This section synthesises the evidence base on how the semiconductor supply chain has been reshaped by converging geopolitical pressures, corporate strategies, policy interventions and technological change. Consistent with the review protocol, findings are organised around four interlocking themes that surfaced repeatedly across the corpus. These are geopolitical risk catalysts and shock drivers, firm-level resilience strategies, policy and regulatory interventions, and emerging trends with system-level implications. The analysis shows which mechanisms transmit geopolitical shocks into operational disruption, how firms have actually responded, under what policy constraints they operate, and with what long-run consequences for the geometry of the global chip ecosystem. Throughout, tensions, trade-offs and boundary conditions are foregrounded rather than list-like inventories of practices.

#### **3.1. Theme 1: Geopolitical Risk Catalysts and Shock Drivers**

Across 2018 to 2024, the semiconductor value chain has been destabilised by a polycentric constellation of state actions, coercive legal instruments, kinetic conflict, upstream material choke points and compounding multi-hazard events. Six sub-themes structure this landscape and together explain why the sector has migrated from background exposure to foreground target.

##### **3.1.1. Sanctions and Export Controls**

Sanctions and export controls emerged as the dominant direct instruments of techno-coercion in the United States–China standoff, with immediate and far-reaching operational effects. The United States Entity List designations of Huawei and 70 affiliates in May 2019 severed access to advanced lithography and design tooling, while the 2020 designation of SMIC arrested node migration toward 7 nanometres (Tse et al., 2024). The 2022 tightening of the Foreign Direct Product Rule was a watershed. It extended jurisdiction extraterritorially to block any export involving United States technology irrespective of manufacturing locus, thereby converting ubiquitous American tooling and intellectual property into a global chokepoint that redefined the feasible frontier for design, tape-out and foundry access (Bu, 2024). Allied alignment reinforced the squeeze. Japan adopted export controls on 23 chip-related items at Washington's urging, and the European Union coordinated materials curbs, limiting substitution pathways and raising the transaction cost of compliance-led workarounds (Aoyama et al., 2024; Glencross, 2024). China's mineral countermeasures, specifically export licences on gallium and germanium introduced in July 2023, signalled reciprocal weaponisation of upstream leverage and exposed the vulnerability of radio frequency, optoelectronic and advanced logic materials pipelines to policy toggles rather than market signals (Farrand, 2025). While the World Trade Organization's rare-earths precedent affirms a residual multilateral constraint, the practical reality is that corporate access to critical tools and inputs is now contingent on politicised licensing regimes rather than open exchange (Huang et al., 2024). The net effect is that controls no longer operate as episodic events. They rewrite the feasibility space of the entire chain and hard-bind allied policy into corporate strategy.

##### **3.1.2. Trade Wars and Tariff Escalation**

Tariff escalation re-priced cross-border flows and catalysed footprint reconsideration. Average United States tariffs on Chinese imports climbed from 3.1 percent to 19.3 percent from 2018 onward, mirrored by Chinese levies of up to 20.3 percent on United States goods, with coverage reaching hundreds of billions of dollars in two-way trade. Behaviour changed in response. Eighty-seven percent of United States manufacturers cited these tariffs as the primary triggers for reshoring decisions, and disruption costs associated with offshore models were estimated at more than twice domestic alternatives (Akinbolajo, 2022).

Historical analogues are instructive. Voluntary Export Restraints on Japanese vehicles prompted strategic circumvention via product upgrading, and the current tariff cycle similarly accelerated China plus one reallocations toward Vietnam, India and Mexico, shifting both the origin–destination calculus and the network topology of chip-adjacent manufacturing (Gereffi et al., 2021; Semeniak, 2025). In short, tariffs functioned as network rewiring devices, not mere fiscal instruments.

### 3.1.3. Military Conflict and Security Tensions

Security shocks translated directly into logistics and energy system disruptions, converting geopolitical risk into time and cost penalties. Red Sea instability and Yemen-linked strikes pushed freight costs up by more than one hundred percent, forced Suez avoidance, added roughly ten days to sailings via the Cape and increased fuel burn by about one million dollars per voyage on key lanes (Rasshyvalov et al., 2024). The Russia Ukraine war raised European energy risk premia, stressing energy-intensive wafer and furnace processes and forcing recalibration of production schedules in parts of the European ecosystem (Hajarath, 2024). Taiwan's so-called silicon shield, responsible for more than ninety percent of advanced-node logic output, remains a geostrategic flashpoint whose coercive shadow induces hedging behaviour and duplicative capital expenditure far beyond the island itself (Glencross, 2024; Hassan, 2025). Policy instruments overlapped with security dynamics. The 2022 Bureau of Industry and Security restrictions on electronic design automation were described domestically in China as a declaration of chip war, reinforcing perceptions of strategic encirclement and accelerating efforts at inward substitution (Bu, 2024). Transmission into downstream sectors has been well documented. Volkswagen's Wolfsburg complex ran at approximately sixty percent below capacity during 2021 to 2022 due to chip shortfalls, illustrating how design and upstream frictions convert into automotive production losses through familiar bottlenecks in microcontrollers and power devices (Xiong et al., 2025). When choke points and control points coincide, contingency buffers cease to be tactical and become structural.

### 3.1.4. Critical Raw-Material Dependencies

Material sovereignty constitutes an independent axis of vulnerability in semiconductor production. China controls an estimated seventy-one percent of global silicon, eighty percent of germanium and ninety-eight percent of gallium processing capacity, making it a structural chokepoint in upstream flows (Farrand, 2025). The European Union's Critical Raw Materials Act set explicit targets for domestic extraction, processing and recycling in an effort to reduce single-country reliance, yet the near-term leverage remains concentrated and policy dependent (Farrand, 2025). The July 2023 gallium licensing requirement demonstrated how upstream concentration can be weaponised with immediate effect on device classes sensitive to that input mix, proving that downstream reshoring without materials depth does little more than relocate the choke. Materials policy is now semiconductor policy in both the doctrinal and operational senses.

### 3.1.5. Geopolitical Risk Metrics and Spillovers

Quantitative evidence confirms systemic entanglement. The Total Connectedness Index increased from a baseline in the high thirties to mid-forties during shocks, with semiconductors flipping from net receivers to net transmitters of shocks and long-run spillovers approaching ninety percent (Huang et al., 2024). The Geopolitical Risk index explains most of its own variance, indicating self-sustaining uncertainty that amplifies across sectors. Spikes align with the 2018 tariff wave, the onset of the pandemic and the 2022 invasion of Ukraine, corroborating qualitative accounts with dynamic connectedness measures. Risk is therefore networked and endogenous. Treating shocks as exogenous blips underestimates persistence and cross-sector propagation into communications infrastructure and rare-earth chains.

### 3.1.6. Multi-hazard Shocks

Pandemic dynamics layered on geopolitical stressors to produce compounding fragility. Between 2020 and 2024, ninety-three percent of firms reported supply disruptions. Global trade fell seven percent in 2020 and inventory-to-sales ratios dropped by fifteen percent as firms struggled to buffer volatility with reduced visibility and elongated lead times (Celestin & Sujatha, 2024). Geopolitical conflicts accounted for roughly a quarter of disruptions while pandemic dynamics drove nearly half. Chip prices spiked, power device shortages cascaded, and case evidence from the automotive sector showed production losses in the millions of units, including a forty thousand vehicle shortfall for a single light truck model due to MOSFET scarcity (Xiong et al., 2025).

Lean just-in-time logics failed under correlated shocks. Strategic buffers and regionalisation transitioned from optional insurance to design parameters. The sector has become an arena of statecraft. Export regimes, tariffs, conflict and minerals policy interact non-linearly. The appropriate analytical posture is not risk management framed as variance minimisation. It is design under constraint, with geopolitics treated as an endogenous feature of the feasible set.

### 3.2. Theme 2: Firm-level Responses and Resilience Strategies

Firms have not stood still. Evidence across six sub-themes shows a decisive pivot from single-objective cost efficiency to multi-objective robustness, albeit with cost, complexity and capability trade-offs that challenge smaller actors and late adopters.

#### 3.2.1. Reshoring and Nearshoring

Reshoring and nearshoring have moved from rhetoric to allocation. In the United States, eighty-seven percent of manufacturers flagged geopolitical disruption as the reshoring trigger and nearly three quarters prioritised resilience over cost, indicating a change in objective functions at the board and procurement levels (Akinbolajo, 2022). Mexico surpassed China as the top United States trading partner in 2023, emblematic of decoupling via regional platforms and signalling durable shifts in origin choices for electronics and chip-adjacent goods (Semeniak, 2025). Within the European Union, regional integration halved disruption vis-à-vis China-reliant peers, confirming the resilience dividend of allied proximity and shared regulatory regimes (Semeniak, 2025). East Asia layered industrial policy atop corporate moves. Japan's incentives, Korea's mega-cluster strategy, Taiwan's reshoring pool and TSMC's diversification into Kumamoto, Saxony and Arizona show how public capital can catalyse private reallocation when access to advanced tools becomes politicised (Aoyama et al., 2024; Hassan, 2025). Huawei's localisation to approximately ninety percent domestic sourcing demonstrates speed under pressure and the feasibility of inward substitution when external access is constrained by rule changes rather than market price signals alone (Tse et al., 2024). The trade-offs are visible. Control improves, but capital intensity rises, scale economies are diluted and regional blocs can duplicate capacity with ambiguous net gain if upstream materials and toolchains remain external.

#### 3.2.2. Diversification and Supplier Switching

Redundancy reduced fragility. Diversification cut delays by about thirty percent in comparative samples, and nearly two thirds of firms expanded regional supplier bases after the pandemic period (Celestin & Sujatha, 2024; Shuvo & Habib, 2024). China plus one deployments into Vietnam, India and Mexico are well documented, but the European asymmetry persists. Forty-four percent of European Union firms remain China-dependent in critical tiers compared with lower intra-EU reliance among peers, revealing a structural overhang that policy has yet to purge (Semeniak, 2025). United Kingdom exposure is acute. More than half of chip clients are United States based and over a quarter of equity is United States held, compounding dependency risk across customers and capital (Rolf et al., 2025). Firms employed hedging on rare-earth exposures and rerouted sensitive orders toward safer hubs, sometimes inducing inventory surges downstream when qualification cycles compressed (Huang et al., 2024; Liu et al., 2024). The trade-off is straightforward. Diversification imposes vetting burdens, elongates qualification lead times and increases governance complexity. In volatile alternates, risk is reallocated rather than removed.

#### 3.2.3. Technological Innovation and Digitalisation

Digital visibility acted as a force multiplier for resilience. Internet of Things telemetry and artificial intelligence assisted planning improved forecast accuracy by roughly thirty-five percent and helped firms pre-empt logistics and scheduling disruptions during high-stress windows such as Suez avoidance (Celestin & Sujatha, 2024; Rasshyvalov et al., 2024). Blockchain-based custody tracking, ERP-integrated scenario engines and machine learning driven traceability expanded adaptive capacity and reduced counterfeit risk, especially in long transit lanes and multi-tier networks where documentation integrity matters for export control compliance as much as for operational planning (Xiong et al., 2025; Hajarath, 2024; Semeniak, 2025). The structural message is that digital first transformation is a resilience imperative rather than a discretionary upgrade in a stable environment (Hajarath, 2024). Yet digitalisation introduces cyber exposure, elevates capital requirements and accentuates talent constraints, particularly in small and medium enterprises and in supplier bases outside high-income jurisdictions. Moreover, data sovereignty regimes complicate cross-border analytics and can blunt the returns to predictive visibility if training data cannot traverse policy borders.

#### 3.2.4. Inventory and Buffer Strategies

Firms pivoted from just-in-time to just-in-case buffering. Long-term chip contracts and safety stock holdings became common after the Suez crisis and amid export control uncertainty, with observed abandonment of lean postures in favour of multi-echelon buffers targeted at chokepoint items (Semeniak, 2025; Rasshyvalov et al., 2024). Trade facilitation gains correlated with higher inventories, and fabless models were relatively less inventory sensitive than integrated device manufacturers, indicating design differences in buffer placement across architectures (Liu et al., 2024). Buffering reduced downtime by about thirty percent in comparative accounts focused on semiconductor

intensive lines (Shuvo & Habib, 2024). The trade-offs are familiar. Working capital is tied up, warehousing and obsolescence risks increase and imprecise targeting can create the illusion of resilience while leaving true bottlenecks unaddressed. The empirical message is to buffer tier deep around specific choke items such as power devices rather than bluntly raising overall days of inventory (Xiong et al., 2025).

### 3.2.5. Strategic Partnerships and Alliances

Collaborative governance filled institutional gaps created by national controls and fragmented rule sets. The Chips-4 platform aligned export screens among core players, while the United States–Taiwan arrangements married defence and technology flows in ways that stabilised specific cross-border production plans (Aoyama et al., 2024; Hassan, 2025). The European Union’s Important Projects of Common European Interest deployed billions of euros across dozens of projects to seed cross-border capability in design, equipment and manufacturing, while Korea–Netherlands channels secured privileged access to lithography ecosystems (Bulfone et al., 2024). Rapidus partnered with IBM to relaunch Japan’s leading edge research agenda and keep the domestic capability ladder intact. At the firm level, collaborations such as Huawei with SMIC accelerated time-to-market under constrained tool access, signalling that alliances can substitute for missing market transactions in a controlled regime (Aoyama et al., 2024; Tse et al., 2024). The risk is durability. Alliances remain hostage to political alignment. Firms can inherit bloc liabilities even as they gain capacity or access.

### 3.2.6. Domestic Substitution and Localisation

Localisation underpins sovereignty aims and appeared across jurisdictions in varied forms. Huawei’s domestic bill of materials intensity, SMIC’s progress on seven nanometres under constraint, TSMC’s overseas nodes, Korea’s goal for material self-reliance by 2030 and China’s target for seventy percent chip self-sufficiency by 2025 exemplify the arc toward internal capability even when components of the toolchain remain external (Tse et al., 2024; Huang et al., 2024; Aoyama et al., 2024; Hassan, 2025). The United States CHIPS narrative linked reshoring to job creation on a very large scale, while the United Kingdom’s compound semiconductor pledge ties localisation to targeted niches where comparative advantage is plausible despite small country size (Akinbolajo, 2022; Rolf et al., 2025). The trade-off is systemic. Over-localisation risks parallel silos, duplicated nodes and retaliatory spirals. Without depth in materials and equipment, local capacity remains partial and exposed. A modal bundle is visible. Firms reshore or nearshore where feasible, diversify suppliers, digitise visibility, buffer selectively, ally strategically and localise critical tiers. The unresolved management problem is optimal mix under binding fiscal, labour and policy constraints, especially for mid-tier firms lacking the balance sheet or policy access of national champions.

## 3.3. Theme 3: Policy and Regulatory Interventions

Policy is no longer a background condition. It is a primary design variable that shapes firm options, capital allocation and sequencing of capability development.

### 3.3.1. United States Industrial Policy and Guardrails

The CHIPS and Science Act constitutes the largest United States industrial intervention since the Second World War. The package includes large-scale incentives, research allocations and a twenty-five percent tax credit, with performance-linked obligations and social guardrails that reach inside corporate decision making (Donnelly, 2023; Bulfone et al., 2024). Crucially, guardrail provisions prohibit recipients from expanding advanced operations in China for a decade, and an executive order constrains outbound capital in sensitive Chinese technology domains, hard-coding a bloc choice into investment strategy for any firm seeking federal support (Hassan, 2025; Bu, 2024). These provisions do not operate as neutral subsidies. They are allocation constraints that relocate capacity, embed political conditionality and pre-commit firms to strategies aligned with a specific policy regime. The near-term effect is strengthened domestic continuity. The medium-term risk is accelerated bifurcation.

### 3.3.2. European Union Chips Act and Strategic Autonomy

The European Union’s package aims to double the bloc’s market share by 2030 but relies on limited new common funding and heavy coordination through existing state aid and collaborative frameworks, notably the Important Projects of Common European Interest (Glencross, 2024; Donnelly, 2023; Bulfone et al., 2024). State aid flexibilities attracted TSMC and Intel to member states with fiscal space, sharpening distributional tensions inside the bloc. Crisis-priority and clawback tools allow Brussels to prioritise supply for critical users in emergencies, introducing an explicit command queue into what had been a largely market governed allocation. The model is coordination heavy and fiscally light. It can shepherd projects but may struggle to match speed and scale without deeper common financing.

### 3.3.3. East Asian Industrial Policy

Japan's programmes, Korea's mega-cluster plan and Taiwan's hedging mix of overseas expansion with sovereignty-minded research and legal shields define a hybrid security industrial playbook that marries public capital to coherent capability ladders (Aoyama et al., 2024; Hassan, 2025). Semiconductor policy doubles as diplomatic currency, as seen in linkages between arms sales and technology cooperation. The hazard is regional escalation. As allied export controls proliferate among friends as well as rivals, coordination costs rise and the risk of mutually constraining rule sets increases.

### 3.3.4. Export-control Regimes and Legal Instruments

The extraterritorial reach of the Foreign Direct Product Rule and the Bureau of Industry and Security controls on design tools are canonical chokepoints in the new regime (Bu, 2024). Japan's controlled items list and earlier curbs on fluorinated materials destined for Korea show that allies can weaponise interdependence, with the effect of narrowing safe substitution corridors even for firms otherwise compliant with United States rules (Aoyama et al., 2024). China's gallium licensing exploits upstream dominance and signals readiness to escalate with instruments outside the traditional tariff playbook (Farrand, 2025). United Kingdom divestment directives and European data governance instruments add layers of techno-sovereignty that intersect with trade, investment screening and data transfer, raising the complexity of multi-jurisdictional compliance (Glencross, 2024; Rolf et al., 2025). The emergent global rule set is asymmetric and fragmented. Firms face compliance surfaces that are thickening and, at times, conflicting.

### 3.3.5. Critical Materials Regulation and Data Sovereignty

Critical materials regulation formalises targets for extraction, processing and recycling within allied jurisdictions, while Asian producers pursue explicit materials self-reliance goals and China continues to use quotas and licences as policy levers (Farrand, 2025; Huang et al., 2024). In parallel, European data governance restricts third-country access to non-personal datasets, trading analytical scale for sovereign control over industrial data flows (Farrand, 2025). Materials and data together form the dual pillars of resilience in the policy imagination. Yet ring-fencing data can degrade cross-border analytics essential for predictive visibility, undermining resilience gains envisaged elsewhere in the policy suite.

### 3.3.6. International Alliances and Multilateral Governance

Bloc coordination persists despite fragmentation. Chips-4, transatlantic alignment on lithography export management, World Trade Organization jurisprudence in rare-earths and hundreds of cross-border collaborations under European frameworks together comprise an incomplete but operational governance layer (Glencross, 2024; Huang et al., 2024; Bulfone et al., 2024). The United Kingdom's High-Tech Observatory and Japan's Rapidus echo trust-based intelligence sharing and joint research as substitutes for single-country breadth in capability. Alliances of this sort are effective at consolidating blocs but are exclusive by design, hardening East-West fault lines and complicating universal standard setting (Rolf et al., 2025; Aoyama et al., 2024). The trade-off is familiar. Near-term coherence within blocs against long-term costs of fragmentation between blocs. Policy is achieving short-run robustness through subsidies, controls and legal shields. It does so at the cost of long-run fragmentation unless allied jurisdictions align standards, skills pipelines and the scope of export controls. Without such coordination, duplication risks becoming destiny and cost curves drift upward without commensurate security dividends.

## 3.4. Theme 4: Emerging trends and future implications

Six trajectories cut across the evidence. These are regionalisation and friend-shoring, digital transformation, market-power re-alignment, decentralised architectures, sustainability integration and workforce renewal. Each promises resilience but embeds asymmetries and execution risks that must be managed.

### 3.4.1. Regionalisation and Friend-shoring

China plus one has matured into bloc-aligned friend-shoring. Vietnam, India and Mexico are principal beneficiaries. Mexico's rise to top United States trading partner is emblematic of a deeper reconfiguration of North American sourcing maps that pull semiconductor-adjacent manufacturing into the regional perimeter (Semeniak, 2025). Within Europe, internal sourcing delivers significantly fewer disruptions than chains anchored in China, reinforcing the case for allied proximity in both policy and operations (Semeniak, 2025). Yet sub-national alignment matters. In the United Kingdom, significant workforce clusters, such as the Midlands share, lack coherent policy

backing. The North-West is similarly under-leveraged relative to its base, revealing implementation gaps that dilute the resilience dividend from geographic rebalancing (Rolf et al., 2025). Friend-shoring works best when internal industrial policy is coherent across territories. Otherwise, national reshoring can produce regional inequalities and execution bottlenecks that blunt the intended resilience gains.

#### 3.4.2. Digital Transformation and Predictive Analytics

Predictive analytics and digital control towers improve forecast accuracy materially and reposition logistics and production planning from reactive to anticipatory modes. Artificial intelligence dashboards, blockchain custody, and enterprise resource planning cognition allow multi-tier visibility and faster exception management during disruptions such as Red Sea diversions (Celestin & Sujatha, 2024; Xiong et al., 2025; Hajarath, 2024; Rasshyvalov et al., 2024; Semeniak, 2025). The caveat is threefold. Capital expenditure requirements are non-trivial, capability gaps widen between large and small firms, and data sovereignty restrictions can compartmentalise data flows, reducing model performance precisely when cross-border inference is needed. Absent governance frameworks that enable lawful and timely data sharing among trusted jurisdictions, digital capacity risks bifurcating along bloc lines and creating a new layer of dependency.

#### 3.4.3. Market-power Realignments

Fabrication power continues to tilt eastward. Taiwan and Korea control more than seventy percent of global fabrication capacity, with additional share gains recorded in 2022 that consolidated their position at advanced nodes (Shuvo & Habib, 2024). The United States retains strong design market share but is exposed to policy shocks on the demand side. A comprehensive ban on sales to China would remove a significant fraction of global revenue for major design houses, illustrating how weaponised interdependence can rebound economically even as it advances strategic aims (Bu, 2024). United Kingdom chipmakers' reliance on United States customers compounds concentration risk and underlines the vulnerability of smaller ecosystems to single-customer and single-market dependence (Rolf et al., 2025). Mexico's ascent in North American trade further shifts assembly and test footprints regionally, changing supplier development pathways over the medium term (Semeniak, 2025). The implication is that absent coordinated allied capacity development in equipment, materials and advanced packaging, node leadership remains geographically precarious.

#### 3.4.4. Decentralised and Blockchain Models

Post-crisis decentralisation strategies use distributed ledger technologies for traceability, regionalised additive manufacturing for spares, and federated enterprise resource planning layers to reduce latency and counterfeit risk along long and politically fragmented routes (Xiong et al., 2025; Semeniak, 2025; Hajarath, 2024). The premise is that decentralisation can absorb shocks by shortening critical paths and improving provenance assurance under export control scrutiny. The constraints are practical. Interoperability remains inconsistent, integration overheads are significant for small suppliers, and jurisdictional data rules can fragment information flows in the same way geopolitics fragments physical flows. Without harmonised standards and trusted data exchange frameworks, decentralised architectures risk reproducing the coordination failures they are designed to solve.

#### 3.4.5. Sustainability and Green Practices

Sustainability has shifted from compliance to risk governance and capital allocation logic. United States and European policies channel investment into low-power architectures and clean energy inputs, and firms report adaptability gains from circular economy models and environmental, social and governance linked robustness indicators (Akinbolajo, 2022; Glencross, 2024; Celestin & Sujatha, 2024; Xiong et al., 2025). The European targets for recycling are directionally correct but modest relative to the rare-earth intensity of modern electronics, and supply chain emissions reductions via artificial intelligence routing and additive manufacturing remain subject to verification (Farrand, 2025; Rasshyvalov et al., 2024). The risk is performativity. Without independent measurement, green resilience can devolve into disclosure compliance without material risk reduction.

#### 3.4.6. Workforce and Capability Development

Human capital is the binding constraint. Programme headlines around reshoring are impressive, but sub-nanometre fabrication skills remain scarce across blocs. Japan's Ångstrom initiative and the Rapidus partnership with IBM aim to rebuild the advanced research and development capability ladder domestically, while European and United Kingdom initiatives tend toward reactive catch-up with targeted niche funding such as compound semiconductors (Akinbolajo, 2022; Aoyama et al., 2024; Hassan, 2025; Glencross, 2024; Rolf et al., 2025). Migration

controls and security vetting slow the formation of transnational technical teams just as fabs internationalise and supply chains regionalise, creating staffing bottlenecks that cannot be solved by capital spending alone. Resilience needs portable human capital and mutual recognition frameworks for specialised training. Otherwise, fabs can be built faster than they can be staffed. The direction of travel is clear. The system is becoming more regional, more digital, more decentralised at the edge, greener in its investment priorities and more dependent on scarce skills. The danger is asymmetric execution. Some blocs will scale the full stack of tools, materials, fabs, talent and data. Others will reproduce new dependencies under a different flag and miss the resilience dividend.

#### **4. Research Gaps and Research Avenues**

Geopolitics has moved from background noise to the organising logic of the semiconductor supply chain. The evidence consolidated in Chapter 4 shows that export controls with extraterritorial reach, retaliatory minerals licensing, logistics chokepoints and subsidy races now co-determine design choices from EDA through front- and back-end manufacturing to distribution (Bu, 2024; Aoyama et al., 2024; Farrand, 2025; Rasshyvalov et al., 2024). At the firm level, reshoring, tier-deep diversification, predictive visibility and just-in-case buffers have become canonical, yet their cost–security trade-offs, scalability and interoperability under bloc-specific policy regimes remain insufficiently understood (Akinbolajo, 2022; Celestin & Sujatha, 2024; Semeniak, 2025). This section surfaces the most salient gaps emerging from our synthesis and sets an agenda for targeted inquiry that can sharpen managerial guidance and inform policy calibration.

##### **4.1. Russia-Ukraine War and Contiguous Supply Risks in Semiconductors**

The war's direct channel to chips is not simply neon or noble gases; it is energy system volatility and transport rerouting that raise wafer-processing costs, disturb furnace schedules and elongate cycle times across Europe's fab clusters (Hajarath, 2024). Secondary effects include supplier distress in energy-intensive upstreams and OSAT schedule slippage when air and sea routes are repriced or delayed (Rasshyvalov et al., 2024; Xiong et al., 2025). Yet we lack comparative evidence on how different fab types (logic vs. analog/power), node classes and packaging technologies absorb energy and freight shocks, and which hedges, power PPAs, on-site generation, multi-port logistics options, actually reduce effective downtime. Future work should map these exposure profiles plant-by-plant and couple them with intervention cost curves so that resilience spend can be prioritised where marginal continuity gains are greatest (Hajarath, 2024).

##### **4.2. Geopolitical Rivalry in High-technology Supply Chains: Semiconductors as the Test Case**

Section 4 showed how FDP, BIS EDA rules and allied controls recast access to tools and IP, while China's germanium licences convert upstream dominance into bargaining power (Bu, 2024; Aoyama et al., 2024; Farrand, 2025). What remains under-analysed is the ripple of these controls through tertiary geographies, Malaysia (OSAT), Japan (chemicals), the Netherlands (lithography supply chains), Germany and Taiwan (new fabs), and the degree to which firms in these sites reconfigure networks to maintain market access without breaching guardrails (Glencross, 2024; Hassan, 2025). Two concrete questions follow. First, how do allied but non-US/EU jurisdictions arbitrage overlapping rule sets to keep cross-border design-fab-OSAT handoffs viable? Second, do bloc-aligned subsidies crowd in truly new capacity or merely relocate existing learning curves, with long-run productivity penalties? Multi-country comparative case studies around TSMC's Kumamoto, Saxony, Arizona nodes, Huawei-SMIC localisation and EU IPCEI projects would illuminate these mechanisms directly (Aoyama et al., 2024; Tse et al., 2024; Bulfone et al., 2024).

##### **4.3. Industry 4.0 for Resilience: from Aspiration to Validated Playbooks**

Predictive analytics, IoT telemetry, blockchain custody and ERP-integrated scenario engines are repeatedly cited as resilience multipliers, with reported forecast accuracy gains of ~35% and demonstrated value during Suez-related detours (Celestin & Sujatha, 2024; Rasshyvalov et al., 2024). However, we lack deployment fidelity: which sensor stacks, data models and alert thresholds actually prevent line stoppages at the die-level or avert kitting failures at OSAT? What are the cyber-risk externalities and talent requirements, especially for SMEs in supplier tiers two and three (Hajarath, 2024; Xiong et al., 2025)? Needed now are design-science studies and field experiments that compare digital-twin architectures across at least three multi-site networks, quantify avoided downtime vs. opex, and specify the minimum viable data for effective early-warning without breaching data-sovereignty constraints (Farrand, 2025). This should be paired with SKU-level evaluations of just-in-case inventory policies, where our synthesis shows benefits but also significant working-capital drag, so that digital visibility and physical buffering are optimised jointly rather than pursued as parallel, potentially duplicative hedges (Liu et al., 2024; Shuvo & Habib, 2024).

#### 4.4. Further Research Avenues

Three cross-cutting gaps merit immediate attention. First, systemic propagation: quantitative connectedness metrics demonstrate semiconductors have flipped from shock receivers to shock transmitters, yet few studies trace the operational pathways by which a design-tool control, a Red Sea detour or a gallium licence converts into node-specific idle time and downstream OEM output loss (Huang et al., 2024; Rasshyvalov et al., 2024). Second, execution asymmetries: EU internal sourcing halves disruption versus China-dependent chains, but within-bloc regional policy gaps, e.g., UK sub-national capability underutilisation, may erode those gains; granular evaluations of place-based policy capacity are scarce (Semeniak, 2025; Rolf et al., 2025). Third, materials sovereignty: CRMA-style targets are ambitious, but empirical assessments of processing and recycling ramp rates, permitting bottlenecks and OEM willingness to offtake recycled inputs at scale remain underdeveloped (Farrand, 2025). Across all three, mixed-method designs that fuse plant-level operations data with policy analytics would move the discourse from plausible prescriptions to validated operating rules.

#### 4.5. Geopolitical Disruptions and Supply Chains, Filling the Blanks in the Semiconductor Record

The literature covers the US-China tariff wave, FDPR/EDA controls, Japan's export lists, EU techno-sovereignty instruments, and China's minerals licensing, but important seams remain. The Japan Korea fluorinated-materials dispute's long-run effects on materials diversification, the UK Newport Wafer Fab divestment's signalling impact on inbound investment, and the WTO rare-earths jurisprudence's deterrent value have not been systematically compared within a semiconductor-specific frame (Aoyama et al., 2024; Glencross, 2024; Huang, 2024; Rolf et al., 2025). Similarly, bloc alliances such as Chips-4 are policy-visible, yet their firm-level consequences for supplier qualification, IP sharing, and export-licensing throughput times are not rigorously documented (Aoyama et al., 2024). Filling these blanks demands longitudinal datasets linking policy events to qualification lead-times, yield trajectories and license-to-ship cycle times, enabling causal inference rather than anecdotal attribution.

### 5. Study Limitations

This study draws on a PRISMA-guided systematic review of a focused set of high-quality sources, synthesised through reflexive thematic analysis. The design privileges transparency in evidence selection and interpretive depth in coding, but it has clear boundaries. First, the corpus is English-language, which risks under-representing Chinese, Korean, and Japanese research communities that are central to semiconductor realities. Second, there is an unavoidable time lag between rapidly evolving industrial policy or corporate moves and their appearance in peer-reviewed outlets. Third, the review omits interviews and proprietary operational datasets, limiting our ability to quantify effect sizes by firm size, tier position, or geography, and to test counterfactuals with high-resolution microdata. These choices trade internal coherence for external granularity: the review is strong on patterned mechanisms and weaker on firm-level heterogeneity and live operational metrics.

### 6. Conclusions

Three conclusions are extracted from study. First, geopolitics has migrated from background noise to endogenous design parameter. Export-control architectures, minerals licensing, conflict-adjacent logistics disruptions, and the politicisation of digital infrastructure reshape what is technically and commercially feasible in design, fabrication, assembly, testing, and distribution. This is not a series of "one-off shocks"; it is a steady state in which rule sets and chokepoints co-determine network topology. Treating such forces as exogenous risk misses how they hard-wire into technology access, node progression, supplier qualification, and route planning. Second, effective resilience is triadic. Redundancy matters, but only when it is tier-deep and component-specific, with qualified alternates for true choke items rather than blanket inventory inflation. Visibility is the multiplier: policy-aware control towers that fuse demand, supply, logistics, and regulatory signals enable faster exception management than static dashboards ever could. Autonomy closes the loop, through targeted localisation where it pays, especially in materials processing, specialty chemicals, and critical tools, while recognising that full autarky is neither attainable nor efficient. The firms that combined these three pillars, redundancy, visibility, autonomy, shifted from reactive continuity to designed-for-volatility operations. Third, policy can overcorrect. Subsidy races and unilateral guardrails deliver near-term capacity but risk fragmented standards, duplicated infrastructure, labour bottlenecks, and higher unit costs without commensurate security dividends. The strategic alternative is governance alignment across allied jurisdictions: interoperable export rules, mutual recognition of skills and certifications, shared test and tooling capacity for crisis deployment, and coordinated data frameworks that preserve the benefits of predictive analytics without eroding sovereignty. Resilience improves when sovereignty and interoperability are treated as complements rather than substitutes. For practitioners, the practical implication is to institutionalise "resilience-by-design" at the board level. Tie uptime and critical-path continuity to executive incentives. Budget for digital visibility and materials

hedging with the same seriousness as capex for geographic diversification. Qualify alternates before they are needed, and treat data governance as a core supply-chain capability, not a compliance afterthought. For policymakers, the imperative is to pivot from competing chequebooks to shared rulemaking: align guardrails, streamline licensing for collaborative R&D, pool scarce talent through portable credentials, and pre-position critical tools and chemicals under jointly managed reserves. Resilience is no longer an insurance policy; it is the operating system. Designing for it requires accepting geopolitics as a fixed constraint, building visibility that sees policy as a signal, and localising smartly where it shifts the calculus. Without those shifts, inside firms and across governments, the sector will pay more, fragment faster, and still remain brittle. With them, it can absorb shocks without surrendering pace, precision, or ambition.

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#### References

- AINVEST. (2025). *South Korea's semiconductor surge: A beacon of resilience in a slowing economy*. <https://www.ainvest.com/news/south-korea-semiconductor-surge-beacon-resilience-slowing-economy-2505/>
- Akinbolajo, O. E. (2022). Reshoring strategies and nearshoring in post-pandemic U.S. supply chain resilience. *International Journal of Science and Research Archive*, 6(2), 174–193. <https://doi.org/10.30574/ijrsra.2022.6.2.0160>
- Alicke, K., & Foster, T. (2024). *Supply chains: Still vulnerable*. McKinsey & Company. <https://www.mckinsey.com/capabilities/operations/our-insights/supply-chain-risk-survey>
- Allianz Trade. (2025). *Shape of trade: Leveraging nearshoring, friendshoring and reshoring to overcome rising uncertainties*. [https://www.allianz-trade.com/en\\_global/news-insights/expert-voices/manufacturing-strategies.html](https://www.allianz-trade.com/en_global/news-insights/expert-voices/manufacturing-strategies.html)
- Aoyama, Y., Song, E., & Wang, S. Y. (2024). Geopolitics and geospatial strategies: The rise of regulatory supply chain controls for semiconductor GPN in Japan, South Korea and Taiwan. *ZFW – Advances in Economic Geography*, 68(3–4), 167–181. <https://doi.org/10.1515/zfw-2024-0046>
- Bender, T. (2023). *Navigating complexities: The semiconductor shortage's effect on the auto industry*. Applied Energy Systems, Inc. <https://www.appliedenergysystems.com/semiconductor-shortages-effect-on-auto-industry/>
- Bradshaw, T., & Acton, M. (2025). Nvidia to spend hundreds of billions on U.S. supply chain, says chief. *Financial Times*. <https://www.ft.com/content/3fd3a717-2fbf-42ef-bb08-5baeccdeb1985>
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101. <https://doi.org/10.1191/1478088706qp0630a>

- Broeders, D., Cristiano, F., & Kaminska, M. (2023). In search of digital sovereignty and strategic autonomy: Normative power Europe to the test of its geopolitical ambitions. *JCMS: Journal of Common Market Studies*, 61(5), 1261–1280. <https://doi.org/10.1111/jcms.13462>
- Bu, Q. (2024). Can de-risking avert supply chain precarity in the face of China–U.S. geopolitical tensions? From sanctions to semiconductor resilience and national security. *International Cybersecurity Law Review*, 5, 413–442. <https://doi.org/10.1365/s43439-024-00125-1>
- Bulfone, F., Di Carlo, D., Bontadini, F., & Meliciani, V. (2024). *Adjusting to new geopolitical realities: Semiconductors industrial policy in the U.S. and EU* (IAI Papers No. 24). Istituto Affari Internazionali.
- Celestin, M., & Sujatha, S. (2024). Impact of global supply chain disruptions on business resilience: Strategies for adapting to pandemics and geopolitical conflicts. *International Journal of Advanced Trends in Engineering and Technology*, 9(2), 44–53. <https://doi.org/10.5281/zenodo.13887198>
- Chatham House. (2023). *The balancing act for the UK's semiconductor strategy*. <https://www.chathamhouse.org/2023/06/balancing-act-uks-semiconductor-strategy>
- Chiang, M. H. (2023). Taiwan Semiconductor Manufacturing Company: A key chip in the global political economy. *East Asian Policy*, 15(1), 36–46. <https://doi.org/10.1142/S179393052300003X>
- China News. (2024). China bans exports to U.S. of gallium, germanium, antimony in response to chip sanctions. *Voice of America*. <https://www.voanews.com/a/china-bans-exports-to-us-of-gallium-germanium-antimony-in-response-to-chip-sanctions/7885380.html>
- Citigroup. (2024). *The U.S.–China chip war: Who dares to win?* <https://www.citigroup.com/global/insights/the-u-s-china-chip-war-who-dares-to-win>
- Davletshin, M., Agrawal, V., & Fugate, B. S. (2018). The influence of supply network fragility on firm equity risk. *Academy of Management Proceedings*, 2018(1), 16366. <https://doi.org/10.5465/AMBPP.2018.16366abstract>
- Deloitte. (2024). *The global semiconductor talent shortage: Key workforce challenges and strategies to overcome them*. <https://www2.deloitte.com/content/dam/Deloitte/us/Documents/technology-media-telecommunications/deloitte-us-the-global-semiconductor-talent-shortage.pdf>
- Department for Science, Innovation and Technology. (2023). *National semiconductor strategy*. UK Government.
- Donnelly, S. (2023). Semiconductor and ICT industrial policy in the U.S. and EU: Geopolitical threat responses. *Politics and Governance*, 11(4), 129–139. <https://doi.org/10.17645/pag.v11i4.7031>
- Dorakh, A. (2024). Interdependence and specialization in the global semiconductor industry. *Journal of Infrastructure, Policy and Development*, 8(6), 2436. <https://doi.org/10.24294/jipd.v8i6.2436>
- Efficio. (2024). *China–Taiwan tensions: Impacts on global supply chains and semiconductor availability*. Efficio Consulting. <https://www.fficioconsulting.com/en-us/resources/china-taiwan-tensions-impacts-on-global-supply-chains-and-semiconductor-availability/>
- Ekatpure, S. R. (2024). Adaptation in global semiconductor supply chains: Insights from the COVID-19 pandemic and strategic responses. *International Journal of Scientific Research in Engineering and Management*, 8(10), 1–5. <https://doi.org/10.55041/IJSREM16710>
- European Commission. (2023). *European Chips Act: Shaping Europe's digital future*. <https://digital-strategy.ec.europa.eu/en/policies/european-chips-act>
- Expert Market Research. (2024). *UK semiconductor market size, share, trends and analysis 2034*. <https://www.expertmarketresearch.com/reports/united-kingdom-semiconductor-market>
- Farrand, B. (2025). The economy–security nexus: Risk, strategic autonomy and the regulation of the semiconductor supply chain. *European Journal of Risk Regulation*, 16, 279–293. <https://doi.org/10.1017/err.2024.63>
- Filippo, A., Fabry, N., & Brühlhart, F. (2022). *Semiconductor value chain structure and prospects for the new global scenario*. Université Paris 1 Panthéon-Sorbonne. <https://www.paris1.pantheonsorbonne.fr/semiconductor-value-chain-structure>
- Financial Times. (2018). *Financial Times*. <https://www.ft.com/content/77c25524-34d1-4b31-91cc-44f1004d6f15>
- Francis, J. R. (2020). COVID-19: Implications for supply chain management. *Frontiers of Health Services Management*, 37(1), 33–38. <https://doi.org/10.1097/HAP.000000000000092>
- Glencross, A. (2024). The geopolitics of supply chains: EU efforts to ensure security of supply. *Global Policy*, 15, 729–739. <https://doi.org/10.1111/1758-5899.13388>
- GlobalFoundries. (2024). *GlobalFoundries and Biden–Harris Administration announce CHIPS and Science Act funding for essential chip manufacturing*. <https://gf.com/gf-press-release/globalfoundries-and-biden-harris-administration-announce-chips-and-science-act-funding-for-essential-chip-manufacturing/>
- Gomez, M., Garcia, S., Rajtmajer, S., Grady, C., & Mejia, A. (2020). Fragility of a multilayer network of intranational supply chains. *Applied Network Science*, 5, 1–21. <https://doi.org/10.1007/s41109-020-00310-1>
- GOV.UK. (2025). *Semiconductor technology*. <https://www.great.gov.uk/campaign-site/grow-your-tech-business-in-the-uk/semiconductor-technology/>
- Guba, E. G. (1989). *Fourth generation evaluation* (Vol. 294). Sage.
- Hajarath, K. C. R. (2024). *Geopolitical trade tensions and their strategic impact on global supply chains*. *SSRN Electronic Journal*. [https://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=5295693](https://papers.ssrn.com/sol3/papers.cfm?abstract_id=5295693)

- Hillrichs, D., & Wöfl, A. (2025). *Complexities and dependencies in the global semiconductor value chain* (EconPol Policy Report No. 54). CESifo. [https://www.econpol.eu/publications/policy\\_report\\_54](https://www.econpol.eu/publications/policy_report_54)
- Huang, F. C. F. (2024). Advancing Taiwan's semiconductor industry: Capitalizing on its comparative advantage at the global, regional, and firm levels. *Revista IECOS*, 25(2), 53–76. <https://doi.org/10.21754/iecos.v25i2.2280>
- Huang, Q., Wang, B., & Lin, J. (2024). The risk spillover between geopolitical risk and China's 5G, semiconductor and rare earth industries. *Heliyon*, 10(22), e40048. <https://doi.org/10.1016/j.heliyon.2024.e40048>
- Hyatt, K., Ryle, P. M., & McKnight, M. A. (2024). Semiconductor production, geopolitics and the CHIPS Act of 2022: A theoretical analysis. *Digital Policy, Regulation and Governance*. Advance online publication. <https://doi.org/10.1108/DPRG-12-2023-0184>
- Ishak, S., Salim, N. A. M., Lazim, N. L., Shaharudin, M. R., & Wahab, S. (2022). A conceptual paper of supply chain adaptive strategies during the COVID-19 pandemic and the impact on performance in semiconductor industries. *Asian Journal of Research in Business and Management*, 4(1), 1–14.
- ITSupplyChain. (2023). *From just-in-time to resilience: How COVID-19 and other disruptions are redefining supply chain management*. <https://itsupplychain.com/from-just-in-time-to-resilience-how-covid-19-other-disruptions-are-redefining-supply-chain-management/>
- Jiang, H., Luo, Y., Xia, J., Hitt, M., & Shen, J. (2023). Resource dependence theory in international business: Progress and prospects. *Global Strategy Journal*, 13(1), 3–57. <https://doi.org/10.1002/gsj.1467>
- JPMorgan. (2023). *Supply chain issues and autos: When will the chip shortage end?* <https://www.jpmorgan.com/insights/global-research/supply-chain/chip-shortage>
- Kitchenham, B., & Charters, S. (2007). *Guidelines for performing systematic literature reviews in software engineering* (Version 2.3). *Engineering*, 45(4), 1051.
- Kleinhans, J. P., & Hess, J. (2021). *Understanding the global chip shortages: Why and how the semiconductor value chain was disrupted*. *Interface*. [https://www.interface-eu.org/storage/archive/files/understanding\\_the\\_global\\_chip\\_shortages.pdf](https://www.interface-eu.org/storage/archive/files/understanding_the_global_chip_shortages.pdf)
- Klingler-Vidra, R., & Kuo, Y. C. (2021). Brexit, supply chains and the contest for supremacy: The case of Taiwan and the semiconductor industry. In *A new beginning or more of the same? The European Union and East Asia after Brexit* (pp. 183–203). [https://doi.org/10.1007/978-981-15-9841-8\\_8](https://doi.org/10.1007/978-981-15-9841-8_8)
- Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics*, 33(1), 159–174. <https://doi.org/10.2307/2529310>
- Lee, J. (2025). South Korea exports to rise for second month on chip boost; tariff risks loom: Reuters poll. *Reuters*. <https://www.reuters.com/markets/asia/south-korea-exports-rise-second-month-chip-boost-tariff-risks-loom-2025-03-28/>
- Li, F. (2024). Vulnerabilities and resilience in China's semiconductor supply chain: A comprehensive analysis. *SHS Web of Conferences*, 208, 01025. <https://doi.org/10.1051/shsconf/202420801025>
- Liu, C., He, T., Liu, F., Liang, S., & Zhang, C. (2024). Trade facilitation, market size, and supply chain efficiency of Taiwan semiconductor companies. *PLOS ONE*, 19(10), e0299322. <https://doi.org/10.1371/journal.pone.0299322>
- Lu, B., & Li, R. (2024). Overload cascading failure detection algorithm for multi-layer supply chain network considering delay probability factor. *RAIRO–Operations Research*, 58(6), 5403–5419. <https://doi.org/10.1051/ro/2024207>
- Makortoff, K. (2025). Nvidia will spend hundreds of billions on U.S. manufacturing, says CEO. *The Guardian*. <https://www.theguardian.com/technology/2025/mar/20/nvidia-us-manufacturing-ceo-jensen-huang-donald-trump>
- Matamis, J. (2025). *China's germanium and gallium export restrictions: Consequences for the United States*. Stimson Center. <https://www.stimson.org/2025/chinas-germanium-and-gallium-export-restrictions-consequences-for-the-united-states/>
- McMorrow, R., Olcott, E., Wu, Z., Li, L., Turton, S., & Cheng, T.-F. (2025). TSMC's big U.S. bet and China's chip tool challenger. *Financial Times*. <https://www.ft.com/content/cf28d27d-30ad-4ad3-8dfo-7cba289c8993>
- Min, M., & Kim, S. (2025). *Chip security: Reconciling industrial subsidies with WTO rules and the national security exception*. *Harvard National Security Journal*. [https://harvardnsj.org/wp-content/uploads/2025/01/Kim\\_16\\_Harvard\\_Natl\\_Sec\\_J\\_1-2025\\_.pdf](https://harvardnsj.org/wp-content/uploads/2025/01/Kim_16_Harvard_Natl_Sec_J_1-2025_.pdf)
- Mishra, A., Gupta, N., & Jha, G. K. (2024). Supply chain resilience: Adapting to global disruptions and uncertainty. *International Journal of Innovative Research in Engineering*, 5(2), 189–196. <https://doi.org/10.59256/ijire.20240502025>
- Mohammed, A., & Khan, S. A. (2022). Global disruption of semiconductor supply chains during COVID-19: An evaluation of leading causal factors. In *Proceedings of the International Manufacturing Science and Engineering Conference* (Vol. 85819, p. V002T06A011). American Society of Mechanical Engineers. <https://doi.org/10.1115/MSEC2022-85306>

- Ning, A., Tziantzioulis, G., & Wentzlaff, D. (2023). Supply chain aware computer architecture. In *Proceedings of the 50th Annual International Symposium on Computer Architecture* (pp. 1–15).  
<https://doi.org/10.1145/3579371.3589052>
- Octopart. (2023). *The just-in-time supply chain shifted to just-in-case*. <https://octopart.com/pulse/p/the-just-in-time-supply-chain-shifted-to-just-in-case>
- Odell, L. A., Dilorenzo, C. D., Dawson, C. A., & Kowalyk, M. D. (2021). Supply Chain Risk in Leading-Edge Integrated Circuits. (Technical Report No. AD1148844). Institute for Defense Analyses. Defense Technical Information Center.
- Owen, S. G. (2024). There's an opportunity for the UK in semiconductors. *Financial Times*.  
<https://www.ft.com/content/84b55ef2-cc66-4a5f-a90b-e2537290413a>
- Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., & Chou, R. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*, 372, n71. <https://doi.org/10.1136/bmj.n71>
- Peterson, D. (2025). *Global semiconductor sales increase 19.1% in 2024; double-digit growth projected in 2025*. Semiconductor Industry Association. <https://www.semiconductors.org/global-semiconductor-sales-increase-19-1-in-2024-double-digit-growth-projected-in-2025/>
- Pratt, M. G. (2009). From the editors: For the lack of a boilerplate: Tips on writing up (and reviewing) qualitative research. *Academy of Management Journal*, 52(5), 856–862. <https://doi.org/10.5465/amj.2009.44632557>
- PwC. (2025). *Digital trends in operations survey*. PwC Consulting.
- Ramani, V., Ghosh, D., & Sodhi, M. S. (2022). Understanding systemic disruption from the COVID-19-induced semiconductor shortage for the auto industry. *Omega*, 113, 102720.  
<https://doi.org/10.1016/j.omega.2022.102720>
- Rasshyvalov, D., Portnoi, Y., Sigaieva, T., Alboshchii, O., & Rozumnyi, O. (2024). Navigating geopolitical risks: Implications for global supply chain management. *Multidisciplinary Review*, 7, e2024spe017.  
<https://doi.org/10.31893/multirev.2024spe017>
- Ravi, S. (2021). *Strengthening the global semiconductor supply chain in an uncertain era*. Semiconductor Industry Association. <https://www.semiconductors.org/strengthening-the-global-semiconductor-supply-chain-in-an-uncertain-era/>
- Robinson, E. (2024). UK government publishes semiconductor sector study. *HLK*. <https://www.hlk-ip.com/news-and-insights/uk-government-publishes-semiconductor-sector-study/>
- Rolf, S., Baines, J., Germann, J., & Starrs, S. (2025). The geographies and geopolitics of industrial policy: Designing a data-driven UK semiconductor strategy. *European Urban and Regional Studies*, 32(2), 115–123.  
<https://doi.org/10.1177/09697764241303838>
- Rulison, L. (2025). GlobalFoundries' expansion starts despite CHIPS Act questions. *Times Union*.  
<https://www.timesunion.com/business/article/global-chip-sales-soar-spending-chips-begin-20225911.php>
- Seitz, A., Ehm, H., Akkerman, R., & Osman, S. (2016). A robust supply chain planning framework for revenue management in the semiconductor industry. *Journal of Revenue and Pricing Management*, 15, 523–533.  
<https://doi.org/10.1057/s41272-016-0068-7>
- Semeniak, M. (2025). Global trends in logistics: The impact of geopolitical factors on supply chains. *The American Journal of Management and Economics Innovations*, 7(3), 46–55.  
<https://doi.org/10.37547/tajmei/Volume07Issue03-07>
- Sevastopulo, D. (2025). US adds dozens of Chinese entities to export blacklist. *Financial Times*.  
<https://www.ft.com/content/91397064-74d3-466e-b122-00c2726859e0>
- Shin, Y. H. (2024). Korean multinational corporations' global expansion strategies in manufacturing sector: Mother factory approach. *International Journal of Internet, Broadcasting and Communication*, 16(1), 269–279.
- Shuvo, T. F., & Habib, M. M. (2024). Shifting market power: The role of supply chain disruptions in redefining global trade dynamics. *Social Lens*, 1(1), 34–46. <https://doi.org/10.69971/sl.1.1.2024.8>
- Slotta, D. (2024). *Taiwan Semiconductor Manufacturing Company*. Statista.  
<https://www.statista.com/topics/7097/taiwan-semiconductor-manufacturing-company/>
- Sterling, T. (2025). EU's Virkkunen says Commission plans new semiconductor support programme. *Reuters*.  
<https://www.reuters.com/technology/eus-virkkunen-says-commission-plans-new-semiconductor-support-programme-2025-03-27/>
- STL Partners. (2023). *What does the semiconductor shortage mean for telecoms?*  
<https://stlpartners.com/articles/strategy/what-does-the-semiconductor-shortage-mean-for-telecoms/>
- Teer, J., & Bertolini, M. (2022). *Reaching breaking point: The semiconductor and critical raw material ecosystem at a time of great power rivalry*. The Hague Centre for Strategic Studies.
- Tse, Y. K., Dong, K., Sun, R., & Mason, R. (2024). Recovering from geopolitical risk: An event study of Huawei's semiconductor supply chain. *International Journal of Production Economics*, 275, 109347.  
<https://doi.org/10.1016/j.ijpe.2024.109347>

- UK Research and Innovation. (2024). £11.5m to improve semiconductor manufacturing and supply chains. <https://www.ukri.org/news/11-5m-to-improve-semiconductor-manufacturing-and-supply-chains/>
- Vernall, M. (2024). *The perils of just-in-time in an era of perpetual supply chain disruption*. LinkedIn. <https://www.linkedin.com/pulse/perils-just-in-time-era-perpetual-supply-chain-mark-vernall-b27cc>
- Weatherbed, J. (2025). US expands export blacklist to keep computing tech out of China. *The Verge*. <https://www.theverge.com/news/636277/us-chinese-export-restrictions-blacklist-80-companies>
- Whittemore, R., & Knafl, K. (2005). The integrative review: Updated methodology. *Journal of Advanced Nursing*, 52(5), 546–553. <https://doi.org/10.1111/j.1365-2648.2005.03621.x>
- World Trade Organization. (2024). *State-aid scoreboard: Semiconductor notifications*. WTO.
- Xiong, W., Wu, D. D., & Yeung, J. H. Y. (2025). Semiconductor supply chain resilience and disruption: Insights, mitigation, and future directions. *International Journal of Production Research*, 63(9), 3442–3465. <https://doi.org/10.1080/00207543.2024.2387074>
- Xueji, S. (2025). The unsettled governance of the dual-use items under Article XXI(b)(ii) GATT: A new battleground for WTO security exceptions. *World Trade Review*, 24(1), 75–100. <https://doi.org/10.1017/S147474562400048X>
- Yan, M. (2023). How techno-nationalism affects technological decoupling between China and the U.S.: Case study of the semiconductor supply chain. *International Journal of Education and Humanities*, 10(3), 10–13. <https://doi.org/10.54097/ijeh.v10i3.11782>
- Yang, S., & Yi, Y. (2021). Effect of technological innovation inputs on global value chains status. *Journal of Global Information Management*, 29(5), 37–54. <https://doi.org/10.4018/JGIM.20210901.0a3>
- Yeung, H. W. C. (2022). Explaining geographic shifts of chip making toward East Asia and market dynamics in semiconductor global production networks. *Economic Geography*, 98(3), 272–298. <https://doi.org/10.1080/00130095.2021.2019010>
- Yonhap News Agency. (2025). S. Korea's exports rise 3.1 pct in March on solid chip sales. <https://en.yna.co.kr/view/AEN20250401002052320>
- Zhang, K. S. (2020). *Turning trash into treasure: A comparative study of e-waste recycling in China and the U.S. through systems thinking* (Doctoral dissertation, Virginia Polytechnic Institute and State University). <https://karenszhang.com/wp-content/uploads/2020/11/Turning-Trash-Into-Treasure.pdf>
- Zhu, H. (2023). Apple Inc.'s massive demand for chips and semiconductors under COVID-19 and its response strategies. *Advances in Economics, Management and Political Sciences*, 9, 377–383. <https://doi.org/10.54254/2754-1169/9/20230361>

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