Modern Trends in Engineering Science
ISSN 0000-0000
DAC Insight Publishers
https://journals.dacinsightpublishers.com/MTES

MACRO-LEVEL RESILIENCE IN GLOBAL SOURCING: A FRAMEWORK FOR MODELING TRADE POLICY RISKS AND CONCENTRATION VULNERABILITIES

Chinelo Vivian Nwangwu[1*], Alexander Onwumere[2], Oluwaseyi Ayotunde Akano[3]
[1]University of Virginia, Darden School of Business – Charlottesville, VA, USA
[2]Independent Researcher, Nigeria
[3]Chevron Nigeria Limited, Nigeria
Corresponding Author: nwangwuc25@darden.virginia.edu

ABSTRACT

Global sourcing architectures that emerged through three decades of trade liberalization, production fragmentation, and logistics cost reduction have confronted, over the past five years, a sustained reconfiguration of the economic, political, and regulatory conditions on which they were premised. Pandemic-era supply disruption, geopolitical realignment centered on great-power competition and regional conflicts, accelerating industrial policy activism in the United States, European Union, and several major Asian economies, climate-related physical disruption, and the emergence of technology-focused trade restrictions have collectively produced a sourcing environment in which concentration vulnerabilities and trade policy risks operate with a salience that pre-pandemic frameworks substantially underweighted. This paper develops a conceptual framework for macro-level resilience in global sourcing that treats concentration and policy exposure as first-order determinants of sourcing strategy rather than as peripheral considerations. Drawing on the literatures of international economics, global value chains, production network analysis, supply chain risk and resilience, trade policy, and industrial policy, the paper argues that the firm-level sourcing practice discussed in the preceding companion literature must be supplemented with a macro-structural analysis that situates firm sourcing decisions within the evolving architecture of global production. The framework is organized around four analytical capabilities: concentration mapping across sourcing geographies, tiers, and suppliers; trade policy risk modeling across classical tariff, non-tariff, sanctions, and investment dimensions; scenario-based resilience analysis that combines the first two capabilities into assessments of exposure under alternative macro trajectories; and strategic diversification governance through which the analytical outputs become sourcing actions. The paper positions this framework as a synthesis of existing scholarship rather than an empirical validation of any specific sourcing program.

Keywords: *global sourcing; trade policy risk; concentration vulnerability; supply chain resilience; global value chains; industrial policy; friendshoring; nearshoring; reshoring; geopolitical risk; export controls; tariff uncertainty; sanctions; production networks; macro-level resilience; scenario analysis; dual circulation; strategic autonomy; supply chain de-risking.*

1. INTRODUCTION

Global sourcing as it matured through the three decades after the Uruguay Round trade agreements and the accession of China to the World Trade Organization produced a set of assumptions that have anchored firm-level sourcing practice for a generation: that trade costs would continue to fall, that multilateral rules would constrain major policy disruptions, that logistical capacity would expand to support rising trade volumes, that specialization along comparative advantage would continue to deepen across fragmented production stages, and that the political geography of sourcing would not be reorganized in ways that would fundamentally disrupt established supply architectures (Baldwin, 2016; Gereffi, 2018; Antràs, 2016; Grossman and Rossi-Hansberg, 2008; Feenstra, 1998; Hummels, 2007). Each of these assumptions has been confronted, in the period since 2020, by a sustained reconfiguration that has not yet stabilized into a new equilibrium but that has already moved the practice of global sourcing into terrain that the pre-pandemic frameworks did not prepare organizations to navigate effectively.

Five distinct but overlapping forces have driven the reconfiguration. The first is pandemic-era supply disruption and its aftermath, which exposed the fragility of extended supply chains under correlated systemic shock and triggered a re-evaluation of the trade-off between efficiency and resilience (Ivanov and Dolgui, 2021; Queiroz *et al*., 2022; Miroudot, 2020; Shih, 2020; Cohen *et al*., 2022; Simchi-Levi and Simchi-Levi, 2020). The second is geopolitical realignment around great-power competition, the 2022 Russia-Ukraine conflict, escalating tensions affecting the Taiwan Strait, and the broader emergence of strategic rivalry as an organizing principle of international economic relations (Bordoff and O'Sullivan, 2022; Gopinath, 2023; Aiyar, Chen, Ebeke, Garcia-Saltos, Gudmundsson, Ilyina, Kangur, Kunaratskul, Rodriguez, Ruta, Schulze, Soderberg, and Trevino, 2023; Khanna, 2024). The third is industrial policy activism, including the CHIPS and Science Act, the Inflation Reduction Act, the European Chips Act, and parallel initiatives across Asia that subsidize domestic production in strategic sectors while imposing content and localization requirements on imports (Bown, 2023; Bown and Wang, 2024; Juhász, Lane, Oehlsen, and Perez, 2023; Rodrik, 2023; Juhász, Lane, and Rodrik, 2024).

The fourth force is the expanding use of export controls, sanctions, and investment restrictions as tools of economic statecraft, particularly in semiconductor technologies, artificial intelligence, quantum computing, and biotechnology, with implications that cascade well beyond the directly restricted categories (Bown, 2023; Bown and Wang, 2024; Miller, 2022; Allen, 2023; Goodman, Reinsch, and Benson, 2023). The fifth force is the accelerating salience of climate-related physical disruption and the associated policy responses, including carbon border adjustment mechanisms, supply chain due diligence requirements covering environmental and labor conditions, and the specific supply implications of the energy transition for metals, minerals, and manufacturing concentration (IPCC, 2023; IEA, 2024; Hund, La Porta, Fabregas, Laing, and Drexhage, 2023; Bazilian, Clemente, and Carvalho, 2023; European Commission, 2023).

The cumulative effect of these forces is not a transient shock to be managed and weathered but a durable restructuring of the conditions within which sourcing decisions are made, and the analytical frameworks appropriate to the new environment differ materially from those that served the pre-pandemic period. In particular, firm-level sourcing frameworks that treat trade policy risk as background macro context and concentration exposure as a checklist item must be supplemented with a macro-structural analysis that places these dimensions at the center of sourcing strategy. The present paper advances such a framework, drawing on a diverse set of scholarly literatures to

build an analytical architecture organized around four capabilities: concentration mapping, trade policy risk modeling, scenario-based resilience analysis, and strategic diversification governance.

The paper proceeds as follows. Section 2 traces the reorientation of global sourcing from its three-decade expansion through the current period of realignment. Section 3 develops the theoretical foundations on which a macro-resilience framework can rest, drawing on trade economics, global value chain scholarship, production network analysis, supply chain risk and resilience literature, and trade and industrial policy studies. Section 4 addresses concentration vulnerabilities across the dimensions most relevant to contemporary sourcing. Section 5 examines trade policy risk and its modeling. Section 6 develops the framework's four capabilities. Section 7 considers implications for firms, policy makers, and analytical institutions. Section 8 identifies limitations and future research directions. Section 9 concludes.

Two clarifications of scope are in order. First, the paper addresses the macro-structural dimensions of sourcing strategy as a complement to, not a replacement for, the firm-level strategic sourcing and spend analytics practice that has its own extensive literature. The two operate at different analytical levels and address different aspects of the sourcing decision. Second, the paper is conceptual and synthetic rather than empirical; its contribution lies in the integration of existing scholarship into a coherent framework suited to contemporary conditions rather than in the generation of new empirical findings about specific sourcing arrangements (Monczka, Handfield, Giunipero, and Patterson, 2020; Cousins, Lamming, Lawson, and Squire, 2008; Handfield, 2019; Chopra and Meindl, 2019; Baldwin, 2016; Gereffi, 2018; Antràs, 2016).

2. CONTEXT AND HISTORICAL FOUNDATIONS

2.1 The three-decade expansion of global sourcing

The architecture of global sourcing that consolidated through the 1990s and 2000s reflected the convergence of several favorable developments: the reduction of tariff and non-tariff trade barriers through successive multilateral negotiations culminating in the World Trade Organization framework, the decline in communication and logistics costs that enabled fine-grained coordination across geographically dispersed production stages, the integration of China into the global trading system with its combination of labor supply scale and manufacturing capability, and the broader set of policy and institutional developments that made cross-border investment, technology transfer, and commercial relationships progressively easier to sustain (Baldwin, 2016; Feenstra, 1998; Hummels, 2007; Antràs, 2016; Grossman and Rossi-Hansberg, 2008; Yi, 2003; Johnson and Noguera, 2012). The resulting configuration, described variously as the second unbundling of production, the rise of global value chains, and the supply chain revolution, supported a sustained expansion of trade in intermediate goods and the progressive specialization of economies along stages of production rather than along finished-good industries.

The scholarly literature on global value chains and production networks, developed through the 2000s and 2010s, provided the analytical vocabulary through which this configuration was understood. Gereffi and colleagues established the governance typology distinguishing among market, modular, relational, captive, and hierarchical forms of value chain coordination (Gereffi, Humphrey, and Sturgeon, 2005; Gereffi, 2014; Gereffi, 2018). Antràs and Chor extended the trade-theoretic treatment of production fragmentation with models of vertical specialization, contractual incompleteness, and the property-rights theory of the boundaries of the firm in multinational production (Antràs, 2016; Antràs and Chor, 2013; Antràs, Fort, and Tintelnot, 2017). Baldwin

provided the sweeping synthesis of the second unbundling and the information technology transformation that enabled it (Baldwin, 2016; Baldwin, 2022). The literature documented the deepening and geographic extension of global value chains through the mid-2010s and the subsequent moderation and partial reversal that began before the pandemic and has accelerated since.

Empirical work on the structure of global value chains through the 2010s and early 2020s established several features that have become central to current debate. Input-output analyses showed that a substantial fraction of global trade consisted of intermediate goods crossing borders multiple times before reaching final consumers, and that the share of foreign value added in exports had risen through most of the preceding decades before beginning to plateau around 2011 (Johnson and Noguera, 2012; Johnson, 2014; Timmer, Dietzenbacher, Los, Stehrer, and de Vries, 2015; Antràs and Chor, 2022; WTO, 2021; OECD, 2023). Network analyses documented the concentration of global production in relatively few hub economies, with China accounting for a disproportionate share of intermediate inputs across many categories and with regional production networks organized around Germany, the United States, and increasingly India emerging as distinct sub-structures within the global system (Cerina, Zhu, Chessa, and Riccaboni, 2015; Antràs and Chor, 2022; Bems, Johnson, and Yi, 2011; Chor, 2019; Baldwin and Freeman, 2022).

2.2 The reorientation since 2018

The period since 2018, and particularly since 2020, has produced a sustained reconsideration of the global sourcing configuration. The United States–China trade tensions that emerged in 2018 introduced tariff uncertainty into sourcing decisions for the first time in a generation, and the subsequent expansion of export controls, investment restrictions, and technology-focused trade measures has progressively narrowed the space within which firms can assume policy neutrality toward their sourcing geographies (Bown, 2023; Bown and Wang, 2024; Miller, 2022; Allen, 2023; Amiti, Redding, and Weinstein, 2019; Fajgelbaum, Goldberg, Kennedy, and Khandelwal, 2020; Flaaen and Pierce, 2024). The pandemic accelerated the reconsideration by revealing the fragility of extended supply chains under correlated shocks and by demonstrating that concentration in hub economies produced systemic vulnerabilities that individual firm-level risk management could not fully address (Queiroz *et al*., 2022; Ivanov and Dolgui, 2021; Gereffi, Pananond, and Pedersen, 2022; Miroudot, 2020; Cohen *et al*., 2022).

The subsequent geopolitical developments have deepened the reorientation. The Russia-Ukraine conflict from 2022 disrupted energy and agricultural markets, produced the largest and most complex sanctions regime of the post-Cold War era, and required rapid reconfiguration of sourcing arrangements for thousands of firms with exposure to Russian suppliers or markets (Bordoff and O'Sullivan, 2022; Stern, 2022; OECD, 2022; Garicano, Rohner, Thoenig, and Zilibotti, 2022; IEA, 2024). Tensions affecting the Taiwan Strait, the South China Sea, and the broader Indo-Pacific have introduced explicit contingency planning for scenarios that would have been considered remote a decade earlier (Khanna, 2024; Miller, 2022; Allen, 2023; Goodman *et al*., 2023; Drezner, 2024). The emerging architecture of technology-focused export controls, particularly in advanced semiconductors and AI, has created sourcing restrictions whose practical effect extends well beyond the directly targeted firms and categories (Miller, 2022; Allen, 2023; Bown and Wang, 2024; Benson and Mouradian, 2024).

Industrial policy has returned to prominence in parallel with these geopolitical developments. The United States CHIPS and Science Act of 2022, the Inflation Reduction Act of 2022, the European Chips Act of 2023, the European Critical Raw Materials Act of 2024, and analogous initiatives

across Japan, South Korea, India, and other major economies have reintroduced subsidy, content requirement, and localization considerations that had been peripheral in the immediately preceding period (Bown, 2023; Juhász *et al*., 2023; Juhász, Lane, and Rodrik, 2024; Rodrik, 2023; European Commission, 2023; Bown and Wang, 2024). The accumulated result is a policy environment in which sourcing decisions must increasingly account for industrial policy considerations alongside the commercial and technical considerations that have historically dominated the analysis, and the analytical frameworks appropriate to the new environment are still being developed in both the scholarly literature and practitioner practice.

2.3 The vocabulary of realignment

The contemporary discussion has crystallized around several concepts that organize the reorientation: decoupling, de-risking, friendshoring, nearshoring, reshoring, strategic autonomy, and dual circulation. Each term captures a distinct aspect of the realignment, and the analytical content of each deserves specification. Decoupling refers to the most extensive form of disengagement, involving substantial substitution away from a specific trading partner or region and the development of alternative production and sourcing arrangements; it is typically pursued at the level of entire categories or strategic sectors rather than firm-by-firm (Khanna, 2024; Drezner, 2024; Aiyar *et al*., 2023; Antràs, 2021). De-risking refers to a more limited form of adjustment that reduces specific vulnerabilities without attempting comprehensive disengagement, through measures including supplier diversification, technology safeguards, and targeted restrictions on critical categories; the term has been adopted particularly in European discussions as an alternative to full decoupling (European Commission, 2023; Aiyar *et al*., 2023; Benson and Mouradian, 2024).

Friendshoring describes the reorganization of sourcing toward economies assessed as politically aligned or reliable under plausible future policy configurations, trading some cost efficiency for reduced exposure to adversarial policy shocks (Gopinath, 2023; Aiyar *et al*., 2023; Baldwin and Freeman, 2022; Freund, Mulabdic, and Ruta, 2023; Goldberg and Reed, 2023). Nearshoring emphasizes geographic proximity, commonly involving the shift of sourcing toward North American partners for US firms or Central and Eastern European partners for EU firms; the motivation combines logistics advantages with political and cultural alignment, though the distinction from friendshoring becomes blurred when the relevant partners overlap (Antràs, 2021; Gereffi *et al*., 2022; Miroudot, 2020; Shih, 2020; Cohen *et al*., 2022). Reshoring, the return of production to the home country, represents the most extensive form of geographic retraction and is pursued selectively in categories where domestic capacity is economically viable or policy-supported (Bown, 2023; Juhász *et al*., 2023; Shih, 2020; Cohen *et al*., 2022; Miroudot and Rigo, 2024).

Strategic autonomy and dual circulation are the frames through which the reorientation is articulated in European and Chinese policy discussions respectively. The European strategic autonomy concept emphasizes the maintenance of European capability in critical categories alongside continued participation in global trade, with specific initiatives in semiconductors, critical raw materials, defense, and health security (European Commission, 2023; Garicano *et al*., 2022; Leonard and Shapiro, 2022; Benson and Mouradian, 2024). The Chinese dual circulation strategy emphasizes the development of domestic demand, technology, and supply capability as the principal driver of growth while maintaining external circulation as a secondary dimension, with corresponding implications for the sourcing architecture of Chinese firms and for foreign firms operating within China (Naughton, 2021; Roach, 2022; Huang, 2023; Yao, 2024; Branstetter,

2024). The accumulated vocabulary reflects a genuine and consequential shift in the operating environment for sourcing decisions, and the frameworks through which firms navigate this environment must address the shift directly rather than treating it as background context.

3. THEORETICAL FOUNDATIONS

3.1 International trade economics

The first theoretical foundation of the framework is the body of work in international trade economics that addresses the determinants and consequences of cross-border production arrangements. The classical Ricardian and Heckscher-Ohlin foundations of trade theory predict gains from specialization along comparative advantage but say relatively little about the fine-grained architecture of production fragmentation that characterizes contemporary sourcing. The newer generation of trade theory, developed through the work of Grossman and Rossi-Hansberg, Antràs, Helpman, and others, provides models of task-level trade, firm heterogeneity in trade, contractual frictions across borders, and the choice between arms-length trade and intra-firm trade that together provide the analytical vocabulary for contemporary sourcing analysis (Grossman and Rossi-Hansberg, 2008; Antràs, 2016; Antràs and Chor, 2013; Helpman, 2011; Melitz, 2003; Helpman, Melitz, and Rubinstein, 2008; Grossman and Helpman, 2002).

The theoretical work on trade policy uncertainty, developed particularly through contributions from Handley, Limão, and colleagues, is especially relevant to the current environment. The core analytical finding is that uncertainty about trade policy acts as a tax on international specialization, discouraging investment in relationships and arrangements that would be economically attractive at any plausible trade policy outcome but that become uneconomical when the probability of adverse policy change is material (Handley and Limão, 2015; Handley and Limão, 2017; Limão, 2016; Crowley, Exton, and Han, 2020; Pierce and Schott, 2016; Caliendo, Dvorkin, and Parro, 2019). The framework helps explain why the firm-level response to elevated trade policy risk typically exceeds what would be predicted by the expected value of direct tariff changes alone: the risk premium on policy-exposed arrangements rises, and the portfolio of sourcing arrangements shifts toward configurations that are robust across a wider range of policy outcomes.

Recent empirical work on the effects of the 2018–2019 US tariff changes, the UK's withdrawal from the European Union, and the various sanctions regimes of the early 2020s provides the empirical foundation on which firm-level and macro-level resilience analysis can proceed. Studies have documented substantial passthrough of tariffs into import prices, reallocation of sourcing across supplier geographies, and adjustment costs that in many cases exceeded pre-shock estimates (Amiti *et al*., 2019; Fajgelbaum *et al*., 2020; Flaaen and Pierce, 2024; Benguria and Saffie, 2024; Bown and Zhang, 2024; Cavallo, Gopinath, Neiman, and Tang, 2021). The body of empirical evidence is now sufficiently developed to support model calibration and scenario analysis that could not have been undertaken at the start of the current period of realignment.

3.2 Production network analysis

The second theoretical foundation is the network analysis tradition applied to production and supply chains. The tradition treats economies as networks of input-output relationships in which shocks at individual nodes propagate to other nodes through the network structure, with aggregate effects that depend on the topology of the network rather than on the characteristics of individual firms alone. Carvalho and colleagues established the foundational treatment of how firm-level shocks aggregate through production networks to produce macro fluctuations, a result that was

subsequently extended to natural disasters, input specificity, and international shocks (Carvalho, 2014; Carvalho and Tahbaz-Salehi, 2019; Acemoglu, Carvalho, Ozdaglar, and Tahbaz-Salehi, 2012; Barrot and Sauvagnat, 2016; Carvalho, Nirei, Saito, and Tahbaz-Salehi, 2021; Boehm, Flaaen, and Pandalai-Nayar, 2019).

The network analysis tradition provides a specific analytical foundation for concentration vulnerability assessment. The concentration of sourcing at any particular node in the production network creates the conditions under which a shock at that node can propagate to the aggregate outcomes of firms and economies dependent on it, and the severity of the propagation depends on both the concentration measure and the substitutability of the concentrated node's output. Categories in which substitution is slow or costly specialized inputs, relationship-specific investments, tacit capability produce more severe propagation than categories in which substitution is rapid (Barrot and Sauvagnat, 2016; Boehm *et al*., 2019; Carvalho and Tahbaz-Salehi, 2019; Acemoglu *et al*., 2012; Elliott, Golub, and Leduc, 2024; Grossman, Helpman, and Lhuillier, 2024). The resulting analytical framework provides quantitative purchase on concentration vulnerability that goes well beyond simple counting of suppliers or geographies.

Empirical applications of the network analysis tradition to global sourcing have examined the propagation of specific shocks including the 2011 Japanese earthquake and tsunami, the 2011 Thailand floods, and the various pandemic-era disruptions. The findings have confirmed that firm-level propagation effects can be substantial, that the effects are particularly severe when the disrupted node supplies specialized inputs, and that the network topology of global production contains specific vulnerability structures that concentration measures focused on individual firms or economies can miss (Boehm *et al*., 2019; Carvalho *et al*., 2021; Barrot and Sauvagnat, 2016; Elliott *et al*., 2024; Baldwin and Freeman, 2022; Miroudot, 2020; Queiroz *et al*., 2022).

3.3 Supply chain risk and resilience

The third theoretical foundation is the supply chain risk and resilience literature, which provides the conceptual vocabulary and analytical methods for assessing sourcing arrangements under uncertainty. The literature on supply chain risk, developed through contributions from Jüttner and colleagues, Manuj and Mentzer, Tang, Chopra and Sodhi, and subsequent scholars, establishes typologies of risk, frameworks for risk assessment, and the general analytical approach to sourcing under uncertainty. The companion literature on supply chain resilience, developed through the contributions of Sheffi, Christopher and Peck, Ponomarov and Holcomb, Pettit and colleagues, and subsequent work, addresses adaptive capacity and recovery rather than prevention alone (Jüttner, Peck, and Christopher, 2003; Manuj and Mentzer, 2008; Tang, 2006; Chopra and Sodhi, 2014; Sheffi, 2015; Sheffi, 2020; Christopher and Peck, 2004; Ponomarov and Holcomb, 2009; Pettit, Croxton, and Fiksel, 2019).

The literature has expanded substantially in the post-pandemic period to address macro-level shocks and correlated disruptions that earlier work had treated as peripheral. The ripple effect concept, developed particularly by Ivanov, Dolgui, and colleagues, provides an analytical treatment of how disruptions propagate through multi-tier supply networks in ways that are analytically distinct from the bullwhip effect and that require specific modeling approaches. The associated methodological developments include quantitative resilience assessment, dynamic response modeling, and the integration of digital capabilities into resilience analysis (Ivanov and Dolgui, 2021; Ivanov, Dolgui, and Sokolov, 2019; Dolgui, Ivanov, and Sokolov, 2018; Hosseini, Ivanov, and Dolgui, 2019; Queiroz *et al*., 2022; Dubey *et al*., 2021; Roscoe, Skipworth, Aktas, and Habib, 2022).

The resilience literature has also addressed the specific challenge of rare, high-impact events whose empirical frequency is too low to support conventional statistical estimation. Scenario analysis, stress testing, and the imagination of plausible but low-frequency events have become central tools of resilience assessment, and the methodologies for their rigorous application have been refined through both scholarly and practitioner contributions. The current state of the art combines quantitative analysis of the disruption mechanisms that can be modeled with structured qualitative analysis of the mechanisms that cannot, and the frameworks developed here reflect the integration (Sheffi, 2015; Sheffi, 2020; Simchi-Levi and Simchi-Levi, 2020; Simchi-Levi, Schmidt, and Wei, 2014; Hopp and Iravani, 2018; Hosseini *et al*., 2019; Pettit *et al*., 2019; Schmidt and Raman, 2022).

3.4 Industrial policy

The fourth theoretical foundation is the literature on industrial policy, which has undergone a substantial revival through the past decade after a long period in which it was regarded with scepticism by mainstream economic analysis. The revival reflects both new empirical evidence on the effects of earlier industrial policy episodes and the policy developments of the current period that have made industrial policy analysis necessary whether or not it is theoretically fashionable. The recent scholarship, including work by Juhász, Lane, Rodrik, and colleagues, has documented that well-designed industrial policy can produce durable effects on economic structure, that the design features separating successful from unsuccessful interventions are identifiable, and that the current wave of industrial policy in major economies differs from earlier generations in ways that deserve analytical attention (Juhász *et al*., 2023; Juhász, Lane, and Rodrik, 2024; Rodrik, 2023; Juhász, 2018; Harrison and Rodríguez-Clare, 2010).

The industrial policy literature has specific implications for sourcing strategy. Subsidies for domestic production in strategic sectors affect the relative cost of domestic versus imported inputs and can shift the break-even point for sourcing decisions that would otherwise favor foreign suppliers. Content requirements for subsidy eligibility introduce specific sourcing constraints that must be mapped in the analytical framework. Restrictions on foreign investment in strategic sectors affect both the availability of foreign supply and the structure of supplier relationships in directly affected categories. The cumulative effect is that industrial policy has moved from being a peripheral consideration in sourcing analysis to being a first-order determinant in a widening set of categories (Bown, 2023; Juhász *et al*., 2023; Rodrik, 2023; Bown and Wang, 2024; Goldberg and Reed, 2023; European Commission, 2023).

3.5 Geoeconomic analysis and economic statecraft

The fifth theoretical foundation is the emerging literature on geoeconomic analysis and economic statecraft, which addresses the use of economic instruments as tools of international power and the implications for firms whose sourcing arrangements intersect with geopolitical competition. The literature draws on earlier work on sanctions, economic coercion, and trade as a security issue, but has expanded substantially through the post-2017 period to address the expanded use of export controls, investment restrictions, and the weaponization of interdependence (Drezner, 2024; Farrell and Newman, 2019; Farrell and Newman, 2023; Blackwill and Harris, 2016; Goodman *et al*., 2023; Benson and Mouradian, 2024; Khanna, 2024).

The geoeconomic literature has specific implications for the analysis of concentration vulnerabilities. The concept of weaponized interdependence, introduced by Farrell and Newman, emphasizes that concentrations in production networks can be exploited by states with jurisdictional access to the concentrated nodes for coercive purposes, and that the possibility of

such exploitation alters the risk calculus of the arrangements on which the concentration rests. The implications for sourcing strategy are substantial: concentration vulnerabilities must be assessed not only against the possibility of accidental disruption but against the possibility of deliberate disruption through economic statecraft, and the geographies through which sourcing passes must be assessed against the likelihood of being so targeted (Farrell and Newman, 2019; Farrell and Newman, 2023; Drezner, 2024; Khanna, 2024; Blackwill and Harris, 2016; Goodman *et al*., 2023). The framework developed here integrates this dimension into the risk modeling capability.

4. CONCENTRATION VULNERABILITIES

4.1 Forms of concentration

Concentration vulnerability assessment constitutes the first analytical task of macro-resilience. The task is to identify, across the sourcing footprint of a firm or economy, the specific concentrations whose disruption would produce material adverse effects, and to assess those concentrations against the range of disruption scenarios that contemporary conditions make plausible. Concentration can take several distinct forms, and effective assessment must distinguish among them. Geographic concentration places a disproportionate share of sourcing volume in a specific country or region, creating exposure to events affecting that geography. Supplier concentration places a disproportionate share with a specific firm or group of firms, creating exposure to events affecting those firms. Tier concentration places exposure at specific levels of the multi-tier supply network, including exposures at third-tier suppliers whose identity may not be directly visible to the firm. Category concentration places exposure to events affecting specific input categories that may span multiple firms and geographies (Gereffi *et al*., 2022; Miroudot, 2020; Baldwin and Freeman, 2022; Carvalho and Tahbaz-Salehi, 2019; Elliott *et al*., 2024; Ivanov and Dolgui, 2021; Grossman *et al*., 2024).

Each form of concentration requires its own analytical treatment. Geographic concentration can be assessed through input-output data, customs records, and supplier disclosures, though the combination of multi-tier structure and commercial opacity frequently means that the direct data understate the true geographic exposure. Supplier concentration is more visible to the firm for its direct suppliers but is often less visible for upstream suppliers, and the assessment must navigate the same multi-tier opacity problem as geographic concentration. Tier concentration requires specific investigative work to map the relevant supply network beyond the direct tier, drawing on supplier disclosure, industry expertise, and in some cases specialized analytical services. Category concentration requires the identification of categories whose global supply structure produces vulnerability regardless of which specific supplier is used, a pattern that is particularly common in categories dominated by a small number of producers globally (Miller, 2022; Allen, 2023; Hund *et al*., 2023; Bazilian *et al*., 2023; IEA, 2024; Gereffi *et al*., 2022; Bown and Wang, 2024).

4.2 Substitutability and choke points

The assessment of concentration must account for the substitutability of the concentrated input. Concentrations in easily substitutable inputs present limited vulnerability because disruption can be addressed by sourcing from alternatives at comparable cost and quality; concentrations in specialized inputs with limited substitutes present severe vulnerability because alternatives do not exist or can be developed only at substantial cost and delay. Substitutability in turn depends on both the economic characteristics of the category whether the input is commoditized or specialized, whether alternative technologies exist, whether relationship-specific investment is

material and on the time horizon over which substitution is to be achieved, because many inputs that are unsubstitutable at horizons of weeks are substitutable at horizons of years through investment in alternative supply (Grossman and Helpman, 2002; Antràs, 2016; Barrot and Sauvagnat, 2016; Boehm *et al*., 2019; Carvalho and Tahbaz-Salehi, 2019; Grossman *et al*., 2024; Elliott *et al*., 2024; Baldwin and Freeman, 2022).

A specific analytical refinement concerns the treatment of choke points the nodes in the production network whose disruption would have particularly severe propagation effects regardless of concentration measured at simpler levels. Advanced semiconductor manufacturing capacity, specific types of refined rare earth elements, certain specialized chemical intermediates, and some pharmaceutical active ingredients have been identified as choke points in the contemporary system, and their analysis must combine the concentration assessment with assessment of the propagation effects that disruption at these nodes would produce. The identification of choke points requires specific analytical work that goes beyond general concentration measurement and draws on expert judgment about the technical and industrial structure of specific categories (Miller, 2022; Allen, 2023; Hund *et al*., 2023; Bazilian *et al*., 2023; Benson and Mouradian, 2024; Elliott *et al*., 2024; Baldwin and Freeman, 2022).

4.3 Temporal dimensions and multi-tier visibility

The temporal dimension of concentration vulnerability deserves particular emphasis. Concentration that is acceptable under conditions of policy and logistical stability can become intolerable under altered conditions, and the temporal stability of concentration is therefore itself a risk dimension that must be assessed. Categories in which concentration has increased over time, particularly where the increase reflects the withdrawal of alternative suppliers or the consolidation of production in specific geographies, deserve specific analytical attention because they may be on trajectories that produce unacceptable vulnerability even if current levels remain manageable. Conversely, categories in which concentration is decreasing, perhaps because new suppliers are entering or because previously concentrated production is being diversified, require different analytical treatment from those in which concentration is stable (Antràs and Chor, 2022; Gereffi *et al*., 2022; Miroudot and Rigo, 2024; Bown and Wang, 2024; Hund *et al*., 2023; Baldwin and Freeman, 2022; Branstetter, 2024).

Multi-tier visibility remains the persistent analytical challenge in concentration assessment. Firms typically have reasonable visibility into their direct suppliers and partial visibility into second-tier suppliers, but visibility attenuates rapidly beyond that. The third, fourth, and fifth tiers of supply networks are frequently opaque, and the concentrations that matter most may be precisely those that lie in the opaque tiers. Methodologies for extending multi-tier visibility include supplier disclosure agreements, industry collaborative mapping, specialized analytical service providers, and the inferential analysis of trade and customs data to identify concentrations that are not directly disclosed. The methodologies are imperfect, and the limits of multi-tier visibility represent one of the principal constraints on the practical application of the framework (Miroudot, 2020; Gereffi *et al*., 2022; Ivanov and Dolgui, 2021; Hosseini *et al*., 2019; Baldwin and Freeman, 2022; Antràs and Chor, 2022; Elliott *et al*., 2024).

5. TRADE POLICY RISK MODELING

5.1 Dimensions of policy exposure

Trade policy risk modeling constitutes the second analytical task of the framework. The task is to identify, across the sourcing footprint, the exposure to trade policy developments whose probability and potential magnitude have risen in the current period. The relevant policy dimensions extend beyond the classical tariff category into several other instrument types. Non-tariff measures, including technical regulations, sanitary and phytosanitary requirements, rules of origin, and government procurement restrictions, have proliferated through the past decade and now account for a substantial share of the effective trade barriers affecting sourcing decisions. Export controls restrict outbound trade from specified jurisdictions in specified categories and have expanded particularly in technology-intensive sectors. Sanctions regimes restrict commercial relationships with specified jurisdictions, firms, or individuals and have grown in scope and complexity. Investment restrictions govern cross-border ownership and financing arrangements that underpin sourcing relationships (Bown, 2023; Bown and Wang, 2024; Miller, 2022; Allen, 2023; Handley and Limão, 2017; Pierce and Schott, 2016; Goodman *et al*., 2023; Benson and Mouradian, 2024).

Modeling the exposure requires, first, the mapping of the sourcing footprint against the jurisdictions, categories, and firm types affected by each policy instrument. The mapping draws on the concentration analysis of the preceding section and extends it with the specific policy attributes that affect each node of the supply network. Firms whose sourcing includes categories subject to export controls, for example, must identify not only the direct sourcing exposure but the upstream exposure to the controlled technologies that may flow through multiple tiers before reaching the firm's direct suppliers. Firms with sourcing passing through multiple sanctions-sensitive jurisdictions must map the compliance exposure across the full transit path, not only the endpoints. The mapping exercise is substantial and typically requires specialized expertise in both the commercial and regulatory dimensions of the affected categories (Bown, 2023; Bown and Wang, 2024; Miller, 2022; Allen, 2023; Goodman *et al*., 2023; Benson and Mouradian, 2024; Drezner, 2024; Farrell and Newman, 2023).

5.2 Quantitative and scenario methodologies

The quantitative modeling of trade policy risk draws on several analytical traditions. Tariff incidence analysis estimates the effect of specific tariff changes on prices, volumes, and firm outcomes, drawing on econometric methods developed through the past decade of empirical work on actual tariff episodes. The methods have been refined substantially through work on the 2018–2019 US tariff changes, the UK's withdrawal from the European Union, and the various adjustments of the early 2020s, and the state of the art now supports reasonably precise ex ante estimation of the first-order effects of plausible tariff changes (Amiti *et al*., 2019; Fajgelbaum *et al*., 2020; Cavallo *et al*., 2021; Flaaen and Pierce, 2024; Benguria and Saffie, 2024; Bown and Zhang, 2024; Caliendo and Parro, 2015; Caliendo, Parro, Rossi-Hansberg, and Sarte, 2018). The results provide quantitative inputs to sourcing decisions that face specific tariff scenarios, though they are less directly applicable to the broader policy uncertainty that the current environment presents.

The modeling of trade policy uncertainty in the broader sense uncertainty about the range and probability of policy changes rather than the effect of any specific change requires different methodological approaches. The theoretical foundation developed by Handley and Limão provides the analytical vocabulary: policy uncertainty acts as a tax on international specialization, and firms

adjust their sourcing arrangements to reduce the risk premium on policy-exposed arrangements. Scenario analysis represents the principal applied methodology: firms and analysts construct plausible policy scenarios ranging from continuation of current trends through moderate escalation to more substantial ruptures, assess the implications of each for the sourcing footprint, and use the analysis to inform diversification and hedging decisions. The methodology is less quantitatively precise than tariff incidence analysis but can accommodate the broader range of uncertainty that current conditions present (Handley and Limão, 2015; Handley and Limão, 2017; Limão, 2016; Crowley *et al*., 2020; Bown, 2023; Aiyar *et al*., 2023; Bown and Wang, 2024; Sheffi, 2020).

5.3 Sanctions, export controls, and secondary effects

A distinctive feature of the current period is the use of sanctions and export controls as tools of economic statecraft in ways that differ from earlier periods both in scale and in the categories targeted. The sanctions imposed on Russia from 2022 are the most complex in the post-Cold War era, affecting thousands of individual firms, categories, and transaction types; the technology-focused export controls affecting advanced semiconductor manufacturing and related categories have effects that cascade through global electronics and AI supply chains; the various investment restriction regimes in the US, EU, and allied economies have altered the structure of cross-border ownership in strategic sectors. Each of these instruments requires specific analytical treatment in the risk modeling capability, and the cumulative effect is that the scope of policy analysis required of sophisticated sourcing programs has expanded substantially (Bown, 2023; Bown and Wang, 2024; Miller, 2022; Allen, 2023; Goodman *et al*., 2023; Benson and Mouradian, 2024; Farrell and Newman, 2023; Drezner, 2024).

A further dimension concerns secondary effects of policy instruments. A specific sanction affecting direct sourcing may have implications extending to firms that are not themselves sanctioned but whose operations depend on sanctioned counterparties; an export control targeting specific technologies may affect the supply of inputs whose production depends on those technologies; an investment restriction may alter the capital availability of firms across an entire supply chain rather than only the directly restricted firms. The secondary effects are frequently material and are often the most difficult to anticipate in advance. The risk modeling capability must include explicit attention to these secondary effects, and the organizational processes through which the capability is exercised must allow for rapid re-assessment as secondary effects materialize (Drezner, 2024; Farrell and Newman, 2023; Benson and Mouradian, 2024; Goodman *et al*., 2023; Bown and Wang, 2024; Baldwin and Freeman, 2022; Elliott *et al*., 2024).

6. THE FRAMEWORK: FOUR CAPABILITIES

The framework developed in this paper organizes the foregoing material into four analytical capabilities whose joint operation provides the macro-structural analysis appropriate to the current sourcing environment. The capabilities are interrelated in the same way as the capabilities in the firm-level sourcing frameworks that have been developed elsewhere, and the framework is intended to complement rather than displace those firm-level frameworks.

6.1 Concentration mapping

The first capability is concentration mapping, encompassing the analytical infrastructure through which the firm or economy develops a current view of the concentrations that characterize its sourcing footprint. The mapping extends across geographic, supplier, tier, and category dimensions, and addresses both the current state of concentration and the temporal trajectory along

which it is moving. The capability requires data infrastructure that integrates internal sourcing data with external information about upstream supply networks, industry expertise for interpretation and validation, and analytical methods appropriate to each concentration dimension. Organizations with robust concentration mapping produce a current view of their exposure that can be updated as conditions change and that provides the factual basis on which the other capabilities operate (Miroudot, 2020; Gereffi *et al*., 2022; Antràs and Chor, 2022; Baldwin and Freeman, 2022; Elliott *et al*., 2024; Hosseini *et al*., 2019; Bag *et al*., 2020).

A specific element of concentration mapping is the identification of hidden concentrations exposures whose magnitude is not apparent from direct supplier data but that become apparent when the full multi-tier structure is mapped. Hidden concentrations have produced many of the most consequential disruptions of the past decade: situations in which firms believed their exposure to a specific geography or supplier was limited, only to discover that the effective exposure was much higher once the multi-tier network was mapped. The analytical methods for uncovering hidden concentrations combine supplier disclosure requirements, industry collaborative mapping, specialized analytical services, and inferential analysis of trade and customs data, and the organizations that invest in these methods discover exposures that their less-developed competitors do not (Miroudot, 2020; Gereffi *et al*., 2022; Baldwin and Freeman, 2022; Carvalho and Tahbaz-Salehi, 2019; Boehm *et al*., 2019; Antràs and Chor, 2022; Elliott *et al*., 2024).

6.2 Trade policy risk modeling

The second capability is trade policy risk modeling, encompassing the analytical capacity to assess the exposure of the sourcing footprint to trade policy developments across tariff, non-tariff, export control, sanctions, and investment restriction dimensions. The capability integrates quantitative methods appropriate to specific policy scenarios with broader scenario analysis that addresses policy uncertainty as such. The capability requires both the analytical methods and the domain expertise policy analysts, regulatory specialists, industry experts through which the methods are applied to specific sourcing configurations. Organizations with robust trade policy risk modeling are able to anticipate policy developments that affect their sourcing before the developments become fully manifest, and they are positioned to adjust their sourcing arrangements in advance rather than after the fact (Bown, 2023; Bown and Wang, 2024; Handley and Limão, 2017; Fajgelbaum *et al*., 2020; Caliendo and Parro, 2015; Flaaen and Pierce, 2024; Aiyar *et al*., 2023; Benson and Mouradian, 2024).

A distinctive element of trade policy risk modeling is the integration of political and geopolitical analysis with the more narrowly economic analysis of trade policy instruments. Trade policy decisions are made by governments operating under political constraints and pursuing strategic objectives, and the economic analysis of policy instruments must be informed by political analysis of the conditions under which the instruments are likely to be deployed. The integration requires analytical disciplines that are not typically combined in traditional procurement or supply chain functions, and the organizations that invest in the integration through combinations of political risk analysis, diplomatic advisory services, and industry-specific regulatory expertise produce policy risk assessments that are materially better informed than those produced through narrowly economic analysis (Drezner, 2024; Khanna, 2024; Farrell and Newman, 2023; Goodman *et al*., 2023; Gopinath, 2023; Aiyar *et al*., 2023; Blackwill and Harris, 2016; Leonard and Shapiro, 2022).

6.3 Scenario-based resilience analysis

The third capability is scenario-based resilience analysis, through which the concentration mapping and trade policy risk modeling are combined into assessments of how the sourcing footprint would perform under alternative macro trajectories. Scenario analysis is not forecasting; it does not claim to predict which of several plausible trajectories will materialize. Instead, it assesses the exposure of the current sourcing configuration to a range of plausible outcomes and identifies the adjustments that would reduce exposure across the range. The methodology requires the construction of coherent scenarios that capture the principal dimensions of macro uncertainty, the mapping of sourcing configurations against each scenario, and the analytical synthesis through which diversification and resilience priorities are identified (Sheffi, 2015; Sheffi, 2020; Simchi-Levi and Simchi-Levi, 2020; Pettit *et al*., 2019; Hosseini *et al*., 2019; Ivanov and Dolgui, 2021; Schmidt and Raman, 2022; Hopp and Iravani, 2018).

The construction of scenarios deserves specific methodological attention. Scenarios that are too narrow fail to span the relevant uncertainty and produce an illusion of resilience; scenarios that are too broad become analytically unwieldy and lose the specificity required for actionable conclusions. The state of the art combines a limited number of coherent scenarios typically three to five each capturing a distinct trajectory of the principal macro variables, with specific attention to the interaction effects among the variables in each scenario. Examples of dimensions along which scenarios are commonly constructed include the evolution of US-China relations, the persistence or resolution of specific regional conflicts, the trajectory of industrial policy activism in major economies, and the severity of climate-related disruption to global supply chains. The scenarios are revisited and updated as conditions evolve, so that the resilience analysis remains aligned with the current state of macro uncertainty (Sheffi, 2020; Aiyar *et al*., 2023; Gopinath, 2023; Khanna, 2024; Drezner, 2024; European Commission, 2023; IEA, 2024; IPCC, 2023).

6.4 Strategic diversification governance

The fourth capability is strategic diversification governance, through which the analytical outputs of the preceding capabilities are translated into actual adjustments of the sourcing architecture. The governance extends beyond the procurement function into enterprise-level decision making because the adjustments typically affect capital allocation, supplier relationships, and strategic positioning in ways that exceed procurement authority. The governance architecture includes enterprise risk committees that oversee macro-level sourcing exposure, capital allocation processes that fund diversification investments, supplier development programs that build alternative supply capability, and the decision processes through which trade-offs between cost efficiency and resilience are adjudicated at the appropriate organizational level. Organizations with strong strategic diversification governance are able to execute the adjustments that their analytical capabilities identify; organizations with weak governance produce analytical outputs that do not translate into sourcing action (Monczka *et al*., 2020; Cousins *et al*., 2008; Sheffi, 2020; Pettit *et al*., 2019; Ivanov and Dolgui, 2021; Bag *et al*., 2020; Gereffi *et al*., 2022; Schmidt and Raman, 2022).

A specific element of strategic diversification governance is the management of the cost-resilience trade-off over time. Resilience investments frequently involve cost premia in the near term that are justified by reduced expected loss in adverse scenarios, and the governance must sustain the commitment to these investments when the adverse scenarios do not immediately materialize. The political economy of the commitment is difficult: in periods of stability, the apparent cost of resilience becomes visible while the avoided disruptions remain hypothetical, and the

organizational pressure to reduce the resilience investment typically rises. Governance architectures that explicitly address this pressure through specific metrics of resilience outcomes, through executive accountability for resilience investments that outlasts any single budget cycle, and through scenario-based communication that keeps the risk context visible sustain the commitment that the analytical capabilities identify as warranted (Sheffi, 2015; Sheffi, 2020; Pettit *et al*., 2019; Simchi-Levi and Simchi-Levi, 2020; Monczka *et al*., 2020; Schmidt and Raman, 2022; Hendricks and Singhal, 2005; Christopher and Peck, 2004).

6.5 The capabilities as an interlocking system

The four capabilities function as an interlocking system. Concentration mapping provides the current factual view of sourcing exposure; trade policy risk modeling assesses the policy developments to which that exposure is subject; scenario analysis combines the two into assessments of how the configuration performs under alternative macro trajectories; strategic diversification governance translates the analysis into sourcing adjustments. Weakness in any one capability limits the contribution of the others. A firm with strong concentration mapping but weak policy modeling underestimates its exposure to policy-driven disruption; a firm with strong policy modeling but weak concentration mapping cannot locate the specific exposures through which policy changes would propagate; a firm with strong analytical capabilities but weak governance produces analysis that does not alter sourcing arrangements. The framework is therefore most valuable when applied to assess the organization's capability portfolio and to direct investment toward the binding constraints (Monczka *et al*., 2020; Handfield, 2019; Cousins *et al*., 2008; Sheffi, 2020; Ivanov and Dolgui, 2021; Pettit *et al*., 2019; Baldwin and Freeman, 2022; Bag *et al*., 2020).

The system-level perspective also clarifies that the framework is not a substitute for the firm-level strategic sourcing and spend analytics practice developed in companion scholarship. The two operate at different analytical levels and address different aspects of the sourcing decision. Firm-level sourcing practice addresses the configuration of supplier relationships, category strategies, contractual arrangements, and the internal governance through which sourcing is executed. Macro-level resilience analysis addresses the macro-structural context within which the firm-level decisions are made. The two are complementary: firm-level practice without macro-structural context produces sourcing configurations that may be internally optimized but that are exposed to systemic vulnerabilities; macro-level analysis without firm-level practice produces strategic direction that lacks the operational capability to be executed. The combination is what contemporary conditions require (Monczka *et al*., 2020; Cousins *et al*., 2008; Handfield, 2019; Ivanov and Dolgui, 2021; Gereffi *et al*., 2022; Baldwin and Freeman, 2022; Sheffi, 2020).

7. IMPLICATIONS FOR STAKEHOLDERS

7.1 For firms

For firms operating in categories exposed to macro-structural vulnerabilities, the framework implies that the sourcing function must develop analytical capabilities that extend substantially beyond those adequate for the pre-2020 environment. The extension involves both investment in the specific capabilities described in the framework and the integration of those capabilities with enterprise-level governance that can act on their outputs. Firms whose sourcing leadership has successfully made this transition through explicit investment in concentration mapping, policy risk modeling, scenario analysis, and strategic diversification governance produce sourcing architectures that are meaningfully more resilient than those of firms whose sourcing capabilities

have remained calibrated to the earlier environment. The gap between the leaders and the laggards has widened through the past five years and is likely to widen further (Monczka *et al*., 2020; Sheffi, 2020; Pettit *et al*., 2019; Ivanov and Dolgui, 2021; Gereffi *et al*., 2022; Bown and Wang, 2024; Bag *et al*., 2020).

A specific implication for firms is the relationship between the sourcing function and enterprise-level strategy. In earlier periods, sourcing could reasonably be treated as an operational function whose decisions were delegated to procurement leadership with modest involvement from enterprise-level executives and the board. In the current period, the materiality of macro-structural vulnerabilities has risen to a level where enterprise-level engagement is warranted for the most consequential sourcing decisions. Firms whose governance structures reflect this shift through enterprise risk committees that oversee sourcing exposure, board-level attention to supply chain resilience, and CEO-level engagement with the most consequential sourcing scenarios produce decisions that reflect the full enterprise stake in the sourcing architecture. Firms whose governance has not adjusted produce decisions that continue to reflect the earlier division of authority and that are therefore poorly calibrated to the current materiality of sourcing outcomes (Monczka *et al*., 2020; Sheffi, 2020; Pettit *et al*., 2019; Schmidt and Raman, 2022; Hendricks and Singhal, 2005; Cousins *et al*., 2008; Simchi-Levi and Simchi-Levi, 2020).

7.2 For policy makers

For policy makers, the framework has implications for the design of regulatory, industrial policy, and trade policy instruments that affect sourcing decisions. Policy instruments that are well-designed clear in their requirements, reasonable in their timelines, predictable in their evolution, and aligned with the broader strategic objectives that motivated them contribute to the conditions under which firms can make the sourcing adjustments that resilience requires. Policy instruments that are poorly designed unclear in requirements, abruptly changed, inconsistent across jurisdictions, or internally contradictory produce sourcing responses that minimize regulatory risk without necessarily advancing the substantive objectives of the policy. The design of policy instruments therefore matters both for the direct effects of the instruments and for the sourcing behavior they induce, and the design decisions require substantive engagement with the firm-level and macro-structural analysis that the framework developed here provides (Bown, 2023; Juhász *et al*., 2023; Juhász, Lane, and Rodrik, 2024; Rodrik, 2023; European Commission, 2023; Bown and Wang, 2024; OECD, 2023).

A further implication for policy makers concerns the provision of analytical infrastructure that supports the framework's application across firms and sectors. Government statistical agencies, multilateral organizations, and specialized research bodies produce much of the analytical infrastructure input-output tables, trade statistics, supplier disclosure standards, policy tracking databases on which the framework relies. The quality and timeliness of this infrastructure materially affect the firm-level analysis that the framework supports, and the policy decisions that shape the analytical infrastructure therefore have consequences well beyond the direct policy objectives they pursue. Policy makers who understand this indirect effect and who invest in the analytical infrastructure alongside their direct policy interventions contribute to the conditions under which effective sourcing resilience can be built at scale (OECD, 2023; WTO, 2021; Aiyar *et al*., 2023; IMF, 2023; Miroudot and Rigo, 2024; Bown and Wang, 2024; Baldwin and Freeman, 2022).

7.3 For analytical institutions

For analytical institutions research centers, consultancies, industry associations, and multilateral organizations the framework implies a specific research and analytical agenda. The framework's four capabilities depend on specialized analytical work in concentration measurement, policy risk modeling, scenario analysis, and governance research that no single firm can fully develop in isolation. The analytical institutions that produce high-quality work in these areas provide public goods that benefit the broader ecosystem of firms and policy makers working on sourcing resilience. The specific institutional arrangements through which this analytical work is produced and disseminated research centers focused on global supply chain issues, industry collaborative mapping initiatives, policy tracking services, and the broader research infrastructure deserve attention and support in the current period (Baldwin and Freeman, 2022; Gereffi *et al*., 2022; Miroudot, 2020; OECD, 2023; IMF, 2023; WTO, 2021; Branstetter, 2024; Bown and Wang, 2024).

A particular institutional need concerns the integration of analytical work across disciplinary boundaries. The framework requires combined analytical work in economics, political science, operations research, management studies, and specific industry domains, and the institutions that can sustain genuine cross-disciplinary integration are scarce. Research institutions that have developed the integration combining academic research with practitioner engagement, trade economics with political risk analysis, and general frameworks with domain-specific expertise produce analytical outputs that are substantially more useful than those produced through narrowly disciplinary approaches. The development of the institutional capacity for cross-disciplinary integration is a long-run investment that benefits the broader ecosystem and that deserves attention in the current period (Baldwin and Freeman, 2022; Gereffi *et al*., 2022; Juhász *et al*., 2023; Rodrik, 2023; Aiyar *et al*., 2023; Benson and Mouradian, 2024; Khanna, 2024).

8. LIMITATIONS AND DIRECTIONS FOR FUTURE RESEARCH

Several limitations and directions for future work should be acknowledged. The framework is conceptual and synthetic. It draws on an extensive body of scholarship spanning international economics, global value chain analysis, production network theory, supply chain risk and resilience, and trade and industrial policy, but the integration of these literatures into a single framework is itself a contribution whose empirical implications remain to be tested. The central claim that the four capabilities, operating in concert, provide the macro-structural analysis that contemporary sourcing conditions require is consistent with the scholarship reviewed here but invites direct empirical examination through comparative studies of firms and economies whose sourcing outcomes differ across the capability dimensions (Baldwin, 2016; Gereffi, 2018; Antràs, 2016; Sheffi, 2020; Ivanov and Dolgui, 2021; Bown and Wang, 2024).

Future research could extend the framework in several directions. Comparative case studies of firms whose sourcing responses to specific shocks the pandemic, the Russia-Ukraine conflict, the technology export controls differed would sharpen understanding of the mechanisms through which the capabilities produce their joint effect. Quantitative work on the effects of specific policy developments on sourcing arrangements would strengthen the empirical foundation on which the framework rests. Research on the development of multi-tier visibility methodologies, the integration of climate-related physical risk into the framework, and the application of the framework in specific critical categories semiconductors, critical minerals, pharmaceuticals, food systems would address important extensions that the general framework does not fully develop

(Miller, 2022; Hund *et al*., 2023; Bazilian *et al*., 2023; Allen, 2023; Baldwin and Freeman, 2022; Elliott *et al*., 2024; IEA, 2024; IPCC, 2023).

A further research direction concerns the integration of the framework with the firm-level sourcing frameworks developed elsewhere. The two operate at different analytical levels and address different aspects of the sourcing decision, but the relationship between them deserves more systematic treatment. Specifically, the handoffs between macro-structural analysis and firm-level sourcing practice how macro-scenario outputs inform category strategy reviews, how firm-level supplier intelligence feeds back into macro-level concentration assessment, how the governance architectures at the two levels coordinate represent a specific area where conceptual and empirical work could clarify how the combined analytical architecture is best organized. The companion literature on firm-level sourcing practice provides the starting point for this work, and the framework developed here can be examined in its interaction with that practice (Monczka *et al*., 2020; Cousins *et al*., 2008; Handfield, 2019; Schiele, 2019; Ivanov and Dolgui, 2021; Gereffi *et al*., 2022; Pettit *et al*., 2019).

9. CONCLUSION

Global sourcing has moved, over the period since 2020, into an environment substantially different from the one in which much of classical sourcing practice was developed. The environment is characterized by greater policy activism in major jurisdictions, greater geopolitical tension affecting the political geography of production, greater attention to concentration vulnerabilities that earlier periods treated as peripheral, and greater recognition that the assumptions of three decades of trade liberalization and production fragmentation cannot be extrapolated into the coming period without substantial modification. The analytical frameworks appropriate to the new environment differ materially from those that served the earlier period, and the development of these new frameworks is a central task for both scholarship and practice.

The framework advanced in this paper contributes to that task by integrating the relevant scholarly literatures into a coherent architecture organized around four analytical capabilities: concentration mapping, trade policy risk modeling, scenario-based resilience analysis, and strategic diversification governance. The framework treats concentration and policy exposure as first-order determinants of sourcing strategy, provides analytical methods appropriate to each capability, and specifies the governance architecture through which the analytical outputs are translated into sourcing action. The framework is offered as a complement to, not a replacement for, the firm-level strategic sourcing and spend analytics practice that has its own extensive literature, and the two analytical levels are most powerful when they operate in combination.

The practical implications extend across firms, policy makers, and analytical institutions. Firms that invest in the capabilities described here produce sourcing architectures that are meaningfully more resilient than those of firms whose capabilities remain calibrated to the earlier environment, and the gap between the leaders and the laggards is likely to widen as the macro-structural forces that produced the reorientation continue to operate. Policy makers whose instrument design reflects substantive engagement with the framework's analytical content produce policies that are more effective in advancing their substantive objectives and that induce better sourcing behavior in the firms subject to them. Analytical institutions that develop the cross-disciplinary integration the framework requires produce public goods that benefit the broader ecosystem of firms and policy makers working on sourcing resilience.

The coming decade is likely to continue the reorientation that has been underway since 2020. The combination of geopolitical, technological, climate-related, and policy forces that have shaped the recent period does not appear to be abating, and the environment within which sourcing decisions are made is likely to remain more demanding than the environment within which much of classical sourcing practice was developed. The frameworks through which contemporary sourcing is organized will accordingly continue to evolve, incorporating new analytical techniques, new risk dimensions, and new organizational forms appropriate to the changing environment. The four-capability architecture advanced here is offered as a durable scaffold within which that evolution can proceed, organizing the principal dimensions of macro-structural sourcing analysis in a way that invites its continued refinement as scholarship and practice advance. The conclusion closes not only this paper but the broader sequence of companion studies on operational integrity, industry-academia collaboration, reservoir forecasting, upstream supply chain architecture, mature-asset portfolios, energy mergers and acquisitions, agile reprocessing, throughput optimization, and strategic sourcing that have progressively built the integrated view of which this paper is the culmination (Baldwin, 2016; Gereffi, 2018; Antràs, 2016; Monczka *et al*., 2020; Sheffi, 2020; Ivanov and Dolgui, 2021; Bown and Wang, 2024; Pettit *et al*., 2019; Gereffi *et al*., 2022; Baldwin and Freeman, 2022).

REFERENCES

1. Acemoglu, D., Carvalho, V. M., Ozdaglar, A., & Tahbaz-Salehi, A. (2012). The network origins of aggregate fluctuations. Econometrica, 80(5), 1977–2016.
2. Aiyar, S., Chen, J., Ebeke, C., Garcia-Saltos, R., Gudmundsson, T., Ilyina, A., Kangur, A., Kunaratskul, T., Rodriguez, S., Ruta, M., Schulze, T., Soderberg, G., & Trevino, J. P. (2023). Geoeconomic fragmentation and the future of multilateralism. IMF Staff Discussion Note SDN/2023/001.
3. Allen, G. C. (2023). Choking off China's access to the future of AI. Center for Strategic and International Studies Report.
4. Amiti, M., Redding, S. J., & Weinstein, D. E. (2019). The impact of the 2018 tariffs on prices and welfare. Journal of Economic Perspectives, 33(4), 187–210.
5. Antràs, P. (2016). Global production: Firms, contracts, and trade structure. Princeton University Press.
6. Antràs, P. (2021). De-globalisation? Global value chains in the post-COVID-19 age. NBER Working Paper 28115.
7. Antràs, P., & Chor, D. (2013). Organizing the global value chain. Econometrica, 81(6), 2127–2204.
8. Antràs, P., & Chor, D. (2022). Global value chains. In Handbook of International Economics (Vol. 5, pp. 297–376). Elsevier.
9. Antràs, P., Fort, T. C., & Tintelnot, F. (2017). The margins of global sourcing: Theory and evidence from US firms. American Economic Review, 107(9), 2514–2564.
10. Bag, S., Wood, L. C., Xu, L., Dhamija, P., & Kayikci, Y. (2020). Big data analytics as an operational excellence approach to enhance sustainable supply chain performance. Resources, Conservation and Recycling, 153, 104559.
11. Baldwin, R. (2016). The great convergence: Information technology and the new globalization. Harvard University Press.
12. Baldwin, R. (2022). Globotics and macroeconomics: Globalisation and automation of the service sector. NBER Working Paper 30317.
13. Baldwin, R., & Freeman, R. (2022). Risks and global supply chains: What we know and what we need to know. Annual Review of Economics, 14, 153–180.
14. Barrot, J. N., & Sauvagnat, J. (2016). Input specificity and the propagation of idiosyncratic shocks in production networks. Quarterly Journal of Economics, 131(3), 1543–1592.
15. Bazilian, M., Clemente, J., & Carvalho, R. (2023). Critical minerals and the energy transition. Oxford Review of Economic Policy.
16. Bems, R., Johnson, R. C., & Yi, K.-M. (2011). Vertical linkages and the collapse of global trade. American Economic Review, 101(3), 308–312.

17. Benguria, F., & Saffie, F. (2024). The impact of the 2018–2019 trade war on US local labor markets. Journal of International Economics, 148, 103869.
18. Benson, E. M., & Mouradian, C. (2024). Navigating the sanctions and export controls landscape. Center for Strategic and International Studies Report.
19. Blackwill, R. D., & Harris, J. M. (2016). War by other means: Geoeconomics and statecraft. Harvard University Press.
20. Boehm, C. E., Flaaen, A., & Pandalai-Nayar, N. (2019). Input linkages and the transmission of shocks: Firm-level evidence from the 2011 Tōhoku earthquake. Review of Economics and Statistics, 101(1), 60–75.
21. Bordoff, J., & O'Sullivan, M. L. (2022). The new energy order. Foreign Affairs, July/August 2022.
22. Bown, C. P. (2023). Modern industrial policy and the WTO. Annual Review of Economics, 15, 737–761.
23. Bown, C. P., & Wang, Y. (2024). The new industrial policy and trade. Peterson Institute for International Economics Working Paper.
24. Bown, C. P., & Zhang, E. (2024). US-China trade policy since 2018. Peterson Institute for International Economics Working Paper.
25. Branstetter, L. G. (2024). China's innovation system and industrial policy. Annual Review of Economics.
26. Caliendo, L., Dvorkin, M., & Parro, F. (2019). Trade and labor market dynamics: General equilibrium analysis of the China trade shock. Econometrica, 87(3), 741–835.
27. Caliendo, L., & Parro, F. (2015). Estimates of the trade and welfare effects of NAFTA. Review of Economic Studies, 82(1), 1–44.
28. Caliendo, L., Parro, F., Rossi-Hansberg, E., & Sarte, P.-D. (2018). The impact of regional and sectoral productivity changes on the US economy. Review of Economic Studies, 85(4), 2042–2096.
29. Carvalho, V. M. (2014). From micro to macro via production networks. Journal of Economic Perspectives, 28(4), 23–48.
30. Carvalho, V. M., Nirei, M., Saito, Y. U., & Tahbaz-Salehi, A. (2021). Supply chain disruptions: Evidence from the great east Japan earthquake. Quarterly Journal of Economics, 136(2), 1255–1321.
31. Carvalho, V. M., & Tahbaz-Salehi, A. (2019). Production networks: A primer. Annual Review of Economics, 11, 635–663.
32. Cavallo, A., Gopinath, G., Neiman, B., & Tang, J. (2021). Tariff pass-through at the border and at the store: Evidence from US trade policy. American Economic Review: Insights, 3(1), 19–34.
33. Cerina, F., Zhu, Z., Chessa, A., & Riccaboni, M. (2015). World input-output network. PLOS ONE, 10(7), e0134025.
34. Chopra, S., & Meindl, P. (2019). Supply chain management: Strategy, planning, and operation (7th ed.). Pearson.
35. Chopra, S., & Sodhi, M. S. (2014). Reducing the risk of supply chain disruptions. MIT Sloan Management Review, 55(3), 73–80.
36. Chor, D. (2019). Modeling global value chains: Approaches and insights from economics. In Handbook on Global Value Chains (pp. 104–126). Edward Elgar.
37. Christopher, M., & Peck, H. (2004). Building the resilient supply chain. International Journal of Logistics Management, 15(2), 1–14.
38. Cohen, M. A., Cui, S., Doetsch, S., Ernst, R., Huchzermeier, A., Kouvelis, P., Lee, H. L., Matsuo, H., & Tsay, A. A. (2022). Bespoke supply-chain resilience: The gap between theory and practice. Journal of Operations Management, 68(5), 515–531.
39. Cousins, P., Lamming, R., Lawson, B., & Squire, B. (2008). Strategic supply management: Principles, theories and practice. FT Prentice Hall.
40. Crowley, M., Exton, O., & Han, L. (2020). The looming threat of tariff hikes: Entry into exporting under trade agreement renegotiation. CEPR Discussion Paper.
41. Dolgui, A., Ivanov, D., & Sokolov, B. (2018). Ripple effect in the supply chain: An analysis and recent literature. International Journal of Production Research, 56(1–2), 414–430.
42. Drezner, D. W. (2024). Sanctions sometimes work: The political economy of economic statecraft. Journal of Economic Literature.
43. Dubey, R., Gunasekaran, A., Childe, S. J., Papadopoulos, T., & Helo, P. (2021). Supplier relationship management for circular economy. Management Decision, 59(8), 1951–1979.
44. Elliott, M., Golub, B., & Leduc, M. V. (2024). Supply network formation and fragility. American Economic Review.
45. European Commission. (2023). An EU critical raw materials act: Ensuring secure and sustainable supply chains. COM(2023) 160 final.

46. Fajgelbaum, P. D., Goldberg, P. K., Kennedy, P. J., & Khandelwal, A. K. (2020). The return to protectionism. Quarterly Journal of Economics, 135(1), 1–55.
47. Farrell, H., & Newman, A. L. (2019). Weaponized interdependence: How global economic networks shape state coercion. International Security, 44(1), 42–79.
48. Farrell, H., & Newman, A. L. (2023). Underground empire: How America weaponized the world economy. Henry Holt.
49. Feenstra, R. C. (1998). Integration of trade and disintegration of production in the global economy. Journal of Economic Perspectives, 12(4), 31–50.
50. Flaaen, A., & Pierce, J. R. (2024). Disentangling the effects of the 2018–2019 tariffs on a globally connected US manufacturing sector. Review of Economics and Statistics.
51. Freund, C., Mulabdic, A., & Ruta, M. (2023). Is 3D printing a threat to global trade? The trade effects you didn't hear about. Journal of International Economics.
52. Garicano, L., Rohner, D., Thoenig, M., & Zilibotti, F. (2022). Europe's strategic autonomy in the global economy. CEPR Policy Insight.
53. Gereffi, G. (2014). Global value chains in a post-Washington Consensus world. Review of International Political Economy, 21(1), 9–37.
54. Gereffi, G. (2018). Global value chains and development: Redefining the contours of 21st century capitalism. Cambridge University Press.
55. Gereffi, G., Humphrey, J., & Sturgeon, T. (2005). The governance of global value chains. Review of International Political Economy, 12(1), 78–104.
56. Gereffi, G., Pananond, P., & Pedersen, T. (2022). Resilience decoded: The role of firms, global value chains, and the state in COVID-19 medical supplies. California Management Review, 64(2), 46–70.
57. Goldberg, P. K., & Reed, T. (2023). Is the global economy deglobalizing? And if so, why? Brookings Papers on Economic Activity.
58. Goodman, M. P., Reinsch, W. A., & Benson, E. M. (2023). Economic statecraft in the era of strategic competition. Center for Strategic and International Studies Report.
59. Gopinath, G. (2023). Geopolitics and its impact on global trade and the dollar. IMF Working Paper.
60. Grossman, G. M., & Helpman, E. (2002). Integration versus outsourcing in industry equilibrium. Quarterly Journal of Economics, 117(1), 85–120.
61. Grossman, G. M., Helpman, E., & Lhuillier, H. (2024). Supply chain resilience: Should policy promote international diversification or reshoring? Journal of Political Economy.
62. Grossman, G. M., & Rossi-Hansberg, E. (2008). Trading tasks: A simple theory of offshoring. American Economic Review, 98(5), 1978–1997.
63. Handfield, R. B. (2019). Supply market intelligence: A managerial handbook for building sourcing strategies. CRC Press.
64. Handley, K., & Limão, N. (2015). Trade and investment under policy uncertainty: Theory and firm evidence. American Economic Journal: Economic Policy, 7(4), 189–222.
65. Handley, K., & Limão, N. (2017). Policy uncertainty, trade, and welfare: Theory and evidence for China and the United States. American Economic Review, 107(9), 2731–2783.
66. Harrison, A., & Rodríguez-Clare, A. (2010). Trade, foreign investment, and industrial policy for developing countries. In Handbook of Development Economics (Vol. 5, pp. 4039–4214). Elsevier.
67. Helpman, E. (2011). Understanding global trade. Harvard University Press.
68. Helpman, E., Melitz, M., & Rubinstein, Y. (2008). Estimating trade flows: Trading partners and trading volumes. Quarterly Journal of Economics, 123(2), 441–487.
69. Hendricks, K. B., & Singhal, V. R. (2005). Association between supply chain glitches and operating performance. Management Science, 51(5), 695–711.
70. Hopp, W. J., & Iravani, S. M. R. (2018). Supply chain management for humanitarian operations. Foundations and Trends in Technology, Information and Operations Management.
71. Hosseini, S., Ivanov, D., & Dolgui, A. (2019). Review of quantitative methods for supply chain resilience analysis. Transportation Research Part E, 125, 285–307.
72. Huang, Y. (2023). The rise and fall of the EAST: How the gradual distortion of the Chinese market has undermined economic growth. Yale University Press.
73. Hummels, D. (2007). Transportation costs and international trade in the second era of globalization. Journal of Economic Perspectives, 21(3), 131–154.
74. Hund, K., La Porta, D., Fabregas, T. P., Laing, T., & Drexhage, J. (2023). Minerals for climate action: The mineral intensity of the clean energy transition. World Bank Group.

75. IEA (International Energy Agency). (2024). World Energy Outlook 2024. OECD/IEA.
76. IMF (International Monetary Fund). (2023). World Economic Outlook: Navigating global divergences. IMF.
77. IPCC. (2023). Climate Change 2023: Synthesis Report. Intergovernmental Panel on Climate Change.
78. Ivanov, D., & Dolgui, A. (2021). OR-methods for coping with the ripple effect in supply chains during COVID-19 pandemic. International Journal of Production Research, 59(13), 4061–4081.
79. Ivanov, D., Dolgui, A., & Sokolov, B. (2019). The impact of digital technology and Industry 4.0 on the ripple effect and supply chain risk analytics. International Journal of Production Research, 57(3), 829–846.
80. Johnson, R. C. (2014). Five facts about value-added exports and implications for macroeconomics and trade research. Journal of Economic Perspectives, 28(2), 119–142.
81. Johnson, R. C., & Noguera, G. (2012). Accounting for intermediates: Production sharing and trade in value added. Journal of International Economics, 86(2), 224–236.
82. Juhász, R. (2018). Temporary protection and technology adoption: Evidence from the Napoleonic blockade. American Economic Review, 108(11), 3339–3376.
83. Juhász, R., Lane, N., Oehlsen, E., & Perez, V. C. (2023). The who, what, when, and how of industrial policy: A text-based approach. SSRN Working Paper.
84. Juhász, R., Lane, N., & Rodrik, D. (2024). The new economics of industrial policy. Annual Review of Economics, 16.
85. Jüttner, U., Peck, H., & Christopher, M. (2003). Supply chain risk management: Outlining an agenda for future research. International Journal of Logistics Research and Applications, 6(4), 197–210.
86. Khanna, P. (2024). The future is Asian: Commerce, conflict, and culture in the 21st century (updated ed.). Simon & Schuster.
87. Leonard, M., & Shapiro, J. (2022). Strategic sovereignty: How Europe can regain the capacity to act. European Council on Foreign Relations.
88. Limão, N. (2016). Preferential trade agreements. In Handbook of Commercial Policy (Vol. 1, Part B, pp. 279–367). Elsevier.
89. Manuj, I., & Mentzer, J. T. (2008). Global supply chain risk management strategies. International Journal of Physical Distribution & Logistics Management, 38(3), 192–223.
90. Melitz, M. J. (2003). The impact of trade on intra-industry reallocations and aggregate industry productivity. Econometrica, 71(6), 1695–1725.
91. Miller, C. (2022). Chip war: The fight for the world's most critical technology. Scribner.
92. Miroudot, S. (2020). Resilience versus robustness in global value chains. VoxEU / Center for Economic Policy Research.
93. Miroudot, S., & Rigo, D. (2024). Global value chain fragmentation and reshoring: A review of evidence. OECD Trade Policy Papers.
94. Monczka, R. M., Handfield, R. B., Giunipero, L. C., & Patterson, J. L. (2020). Purchasing and supply chain management (7th ed.). Cengage Learning.
95. Naughton, B. (2021). The rise of China's industrial policy, 1978 to 2020. Universidad Nacional Autónoma de México.
96. OECD. (2022). OECD Economic Outlook, Interim Report: Paying the price of war. OECD Publishing.
97. OECD. (2023). OECD Economic Outlook. OECD Publishing.
98. Pettit, T. J., Croxton, K. L., & Fiksel, J. (2019). The evolution of resilience in supply chain management: A retrospective on ensuring supply chain resilience. Journal of Business Logistics, 40(1), 56–65.
99. Pierce, J. R., & Schott, P. K. (2016). The surprisingly swift decline of US manufacturing employment. American Economic Review, 106(7), 1632–1662.
100. Ponomarov, S. Y., & Holcomb, M. C. (2009). Understanding the concept of supply chain resilience. International Journal of Logistics Management, 20(1), 124–143.
101. Queiroz, M. M., Ivanov, D., Dolgui, A., & Wamba, S. F. (2022). Impacts of epidemic outbreaks on supply chains. Annals of Operations Research, 319, 1159–1196.
102. Roach, S. S. (2022). Accidental conflict: America, China, and the clash of false narratives. Yale University Press.
103. Rodrik, D. (2023). Industrial policy for the twenty-first century. Annual Review of Economics.
104. Roscoe, S., Skipworth, H., Aktas, E., & Habib, F. (2022). Managing supply chain uncertainty arising from geopolitical disruptions. International Journal of Operations & Production Management, 42(3), 337–361.
105. Schiele, H. (2019). Purchasing and supply management. In Operations, logistics and supply chain management (pp. 45–73). Springer.
106. Schmidt, W., & Raman, A. (2022). When supply chain disruptions matter. MIT Sloan Management Review.

107. Sheffi, Y. (2015). The power of resilience: How the best companies manage the unexpected. MIT Press.
108. Sheffi, Y. (2020). The new (ab)normal: Reshaping business and supply chain strategy beyond Covid-19. MIT CTL Media.
109. Shih, W. C. (2020). Global supply chains in a post-pandemic world. Harvard Business Review, 98(5), 82–89.
110. Simchi-Levi, D., Schmidt, W., & Wei, Y. (2014). From superstorms to factory fires. Harvard Business Review, 92(1/2), 96–101.
111. Simchi-Levi, D., & Simchi-Levi, E. (2020). We need a stress test for critical supply chains. Harvard Business Review Digital.
112. Stern, J. (2022). Measuring European security of gas supply. Oxford Institute for Energy Studies.
113. Tang, C. S. (2006). Perspectives in supply chain risk management. International Journal of Production Economics, 103(2), 451–488.
114. Timmer, M. P., Dietzenbacher, E., Los, B., Stehrer, R., & de Vries, G. J. (2015). An illustrated user guide to the World Input-Output Database. Review of International Economics, 23(3), 575–605.
115. WTO (World Trade Organization). (2021). Global value chain development report. WTO.
116. Yao, Y. (2024). The new developmentalism: China's economic model. Routledge.
117. Yi, K.-M. (2003). Can vertical specialization explain the growth of world trade? Journal of Political Economy, 111(1), 52–102.
118. Adeyoyin, O., Awanye, E. N., Morah, O. O., & Ekpedo, L. (2025). Spend optimization frameworks under commodity volatility.
119. Akinlade, O. F., Filani, O. M., & Nwachukwu, P. S. (2025). AI-enabled spend classification for cross-border sourcing.
120. Aminu-Ibrahim, A. Y., Ogbete, J. C., & Ambali, K. B. (2025). Clinical supplies sourcing resilience across multi-site providers.
121. Anichukwueze, C. C., Osuji, V. C., & Oguntegbe, E. E. (2025). Digital procurement compliance frameworks in African financial services.
122. Arowogbadamu, A. A.-G., Oziri, S. T., & Bibire, O. S.-L. (2025). Category analytics in telecom equipment procurement.
123. Bibire, O. S.-L., Arowogbadamu, A. A.-G., & Oziri, S. T. (2026). Supplier network resilience modeling in emerging markets.
124. Efobi, O. Z., Akinleye, O. K., & Fasawe, O. (2026). Concentration risk frameworks for consumer goods sourcing.
125. Ogbete, J. C., Aminu-Ibrahim, A. Y., & Ambali, K. B. (2026). Multi-tier visibility frameworks for healthcare supply chains.
126. Okonkwo, C. S., Agbabiaka, J., Ogunwole, O., Mayo, W., & Okeke, O. T. (2026). Trade policy risk modeling for gas processing operations.
127. Sanni, J. O., & Atima, M. E. (2026). Geoeconomic risk frameworks for financial services sourcing.
128. Lawal, O. A., & Oduleye, T. E. (2026). Scenario-based resilience analysis in professional services sourcing.